Airport Capacity

Limits, Technology, Strategy

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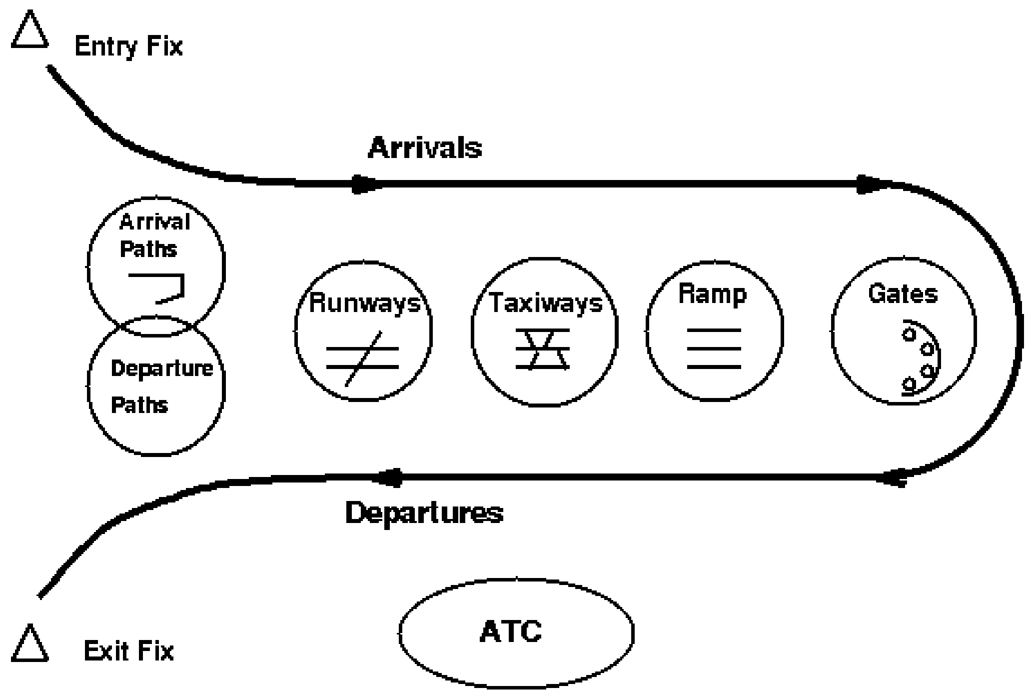
Airport System Capacity Limit Factors

- **Runways**
- **Weather**
  - ☐ Capacity Variability
- **Gates**
- **Downstream Constraints**
- **Controller Workload**
- **Landside Limits**
  - ☐ Terminals
  - ☐ Road Access
- **Environmental**
  - ☐ Community Noise
  - ☐ Emissions
- **Safety**



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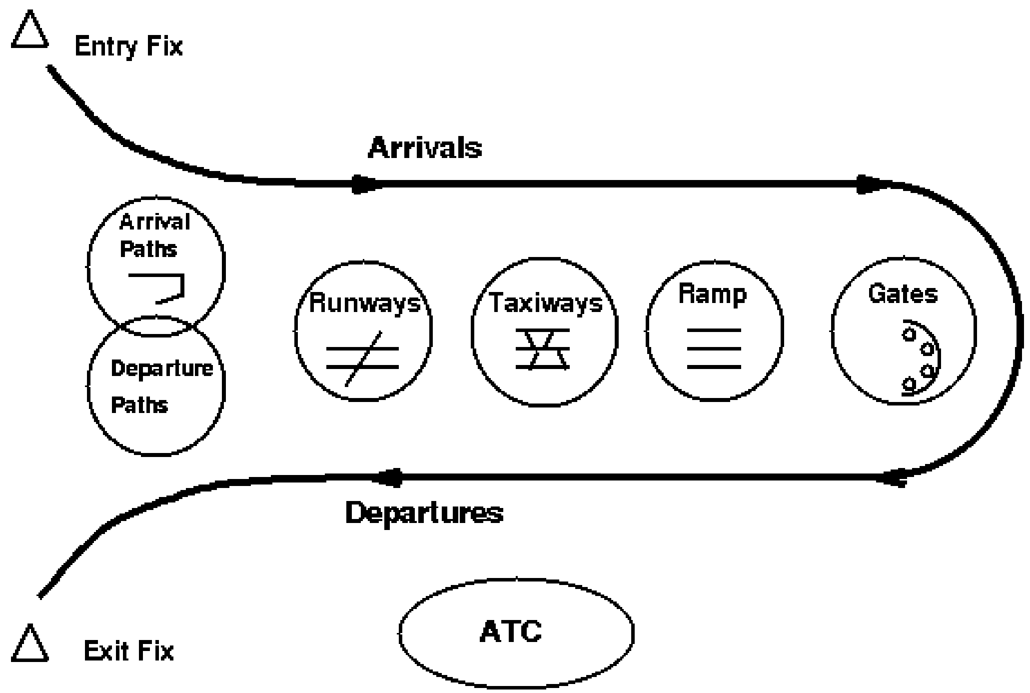
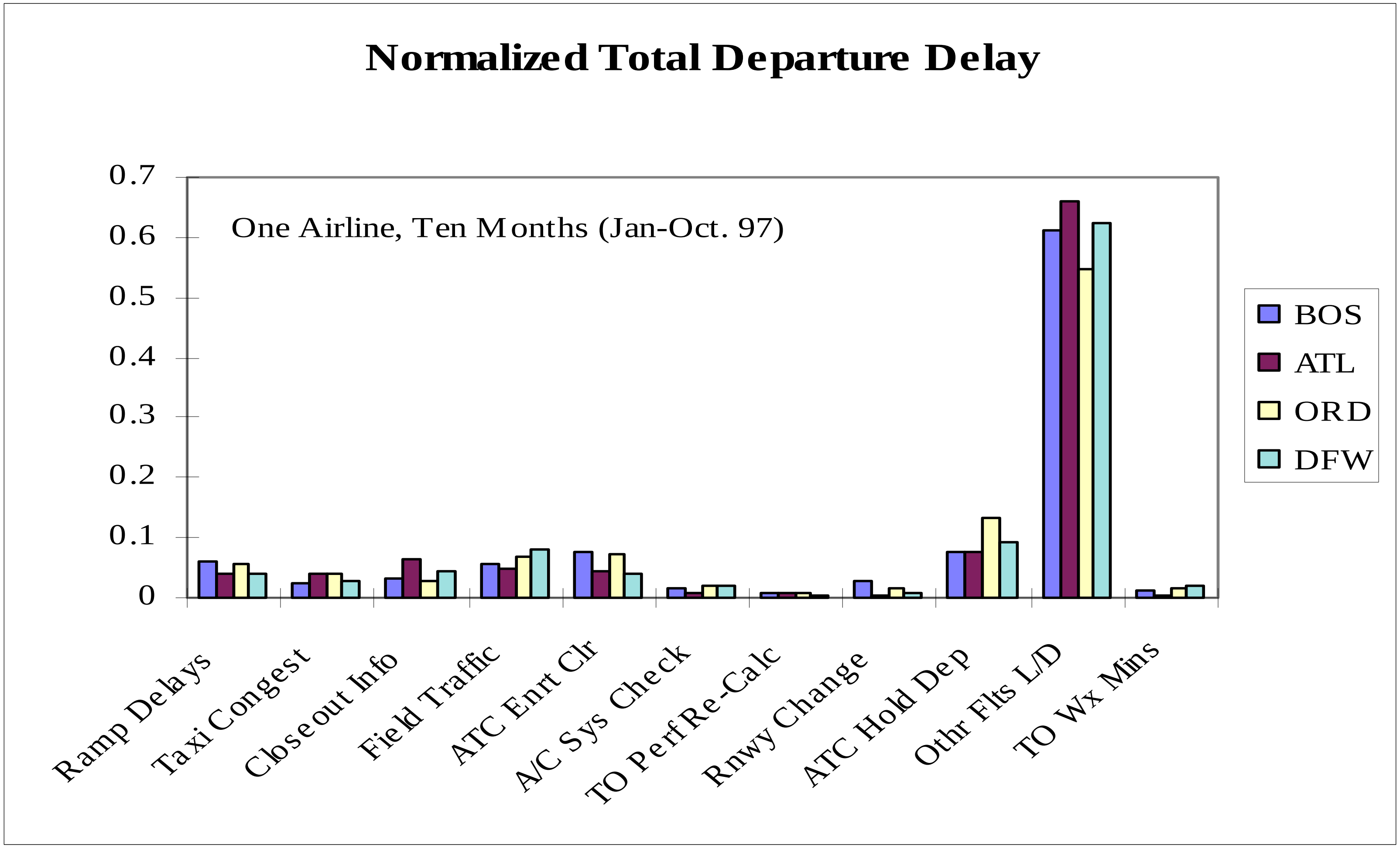


ACARS Constraint Identification (Departure)



Separation Requirements for Arrival (Same Runway)

- **Wake Turbulence Requirement**
  - ☐Radar Separation requirements

Trailing Aircraft

Leading Aircraft

	Heavy	Large	Small
Heavy	4	5	5
B757	4	4	5
Large	3(2.5)	3(2.5)	4
Small	3(2.5)	3(2.5)	3(2.5)

  - ☐Visual Separation requirements
    - ◆ Pilots Discretion
- **Preceding arrival must be clear of runway at touchdown**
  - ☐Runway Occupancy time

Separation Requirements for Departure (Same Runway)

- **Wake Turbulence is NOT a Factor**
  - Takeoff roll after leading takeoff is airborne AND:
    satisfied distance separations, OR
    cleared runway end or turned out of conflict

Trailing departure

Leading departure		Cat I	Cat II	Cat III
	Cat I (small, single prop)	3000	4500	6000
	Cat II (small, twin prop)	3000	4500	6000
	Cat III (all other)	6000	6000	6000

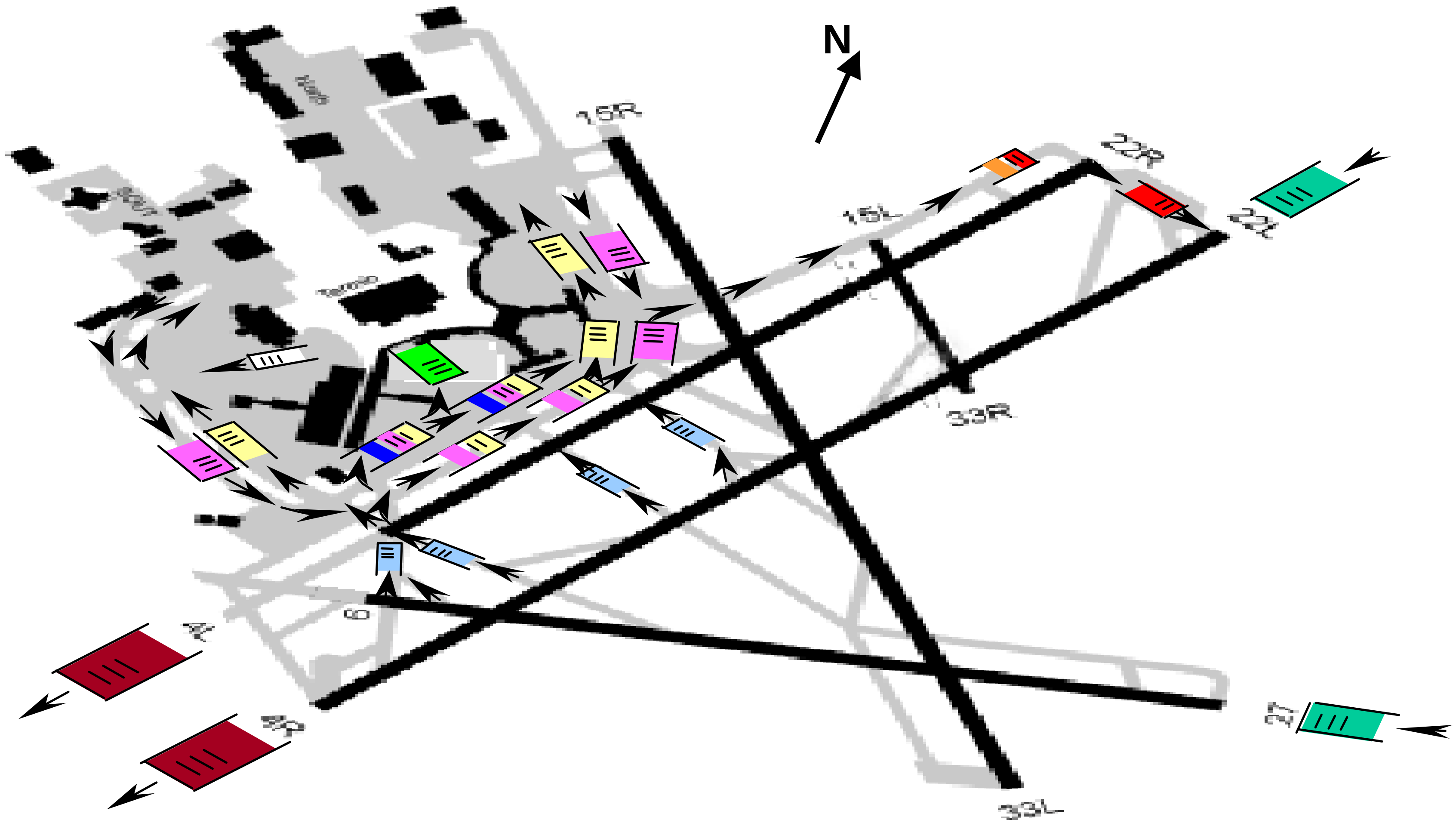
- **Wake Turbulence Application**
  - Trailing takeoff clearance min after leading Heavy or B757 takeoff roll, OR
  - Insure radar separations (miles), when trailing aircraft is airborne

Trailing departure

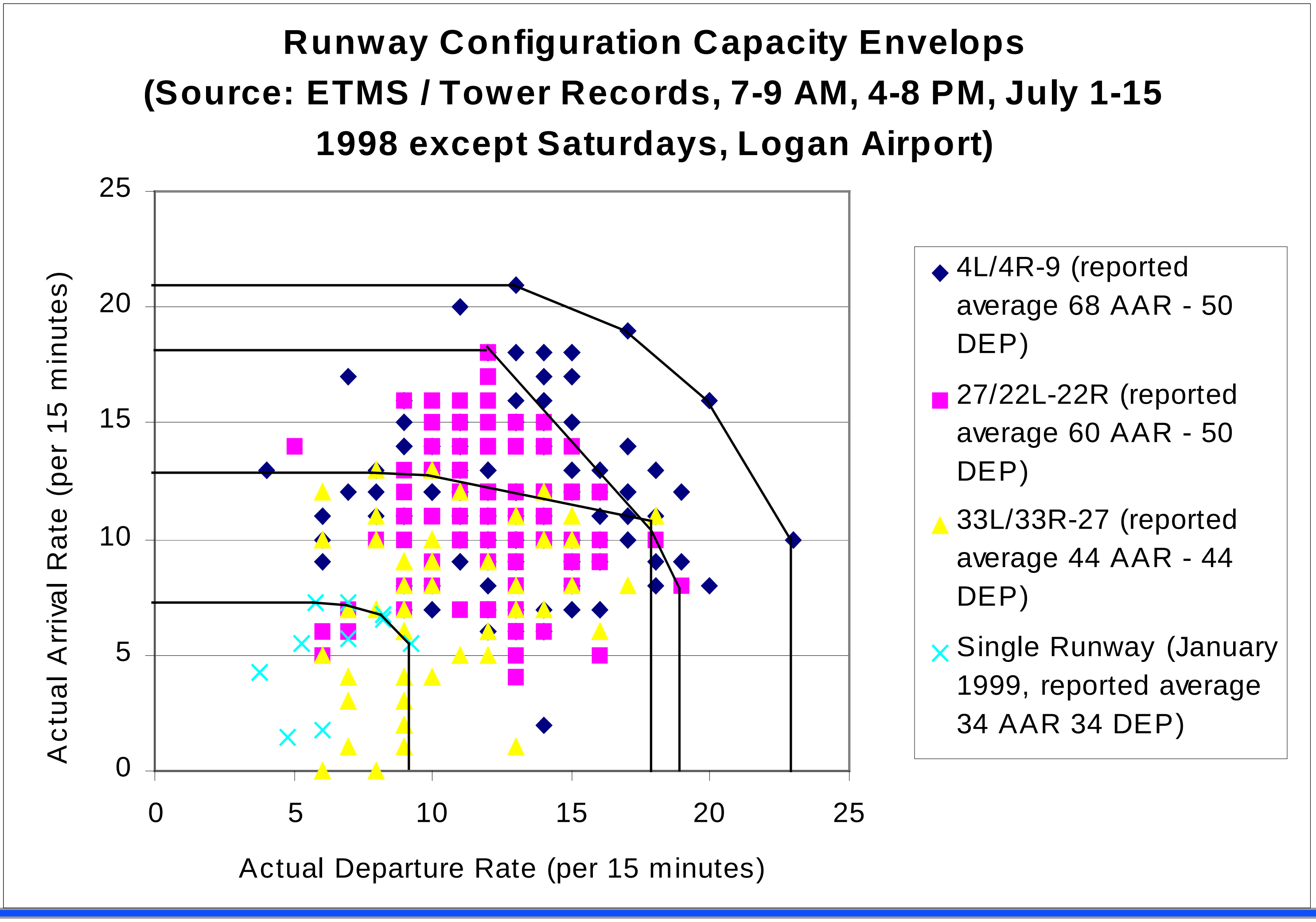
Leading departure		Heavy	Large	Small
	Heavy	4	5	5
	B757	4	4	5

- **Takeoff clearance is granted when preceding landing is clear of the runway**

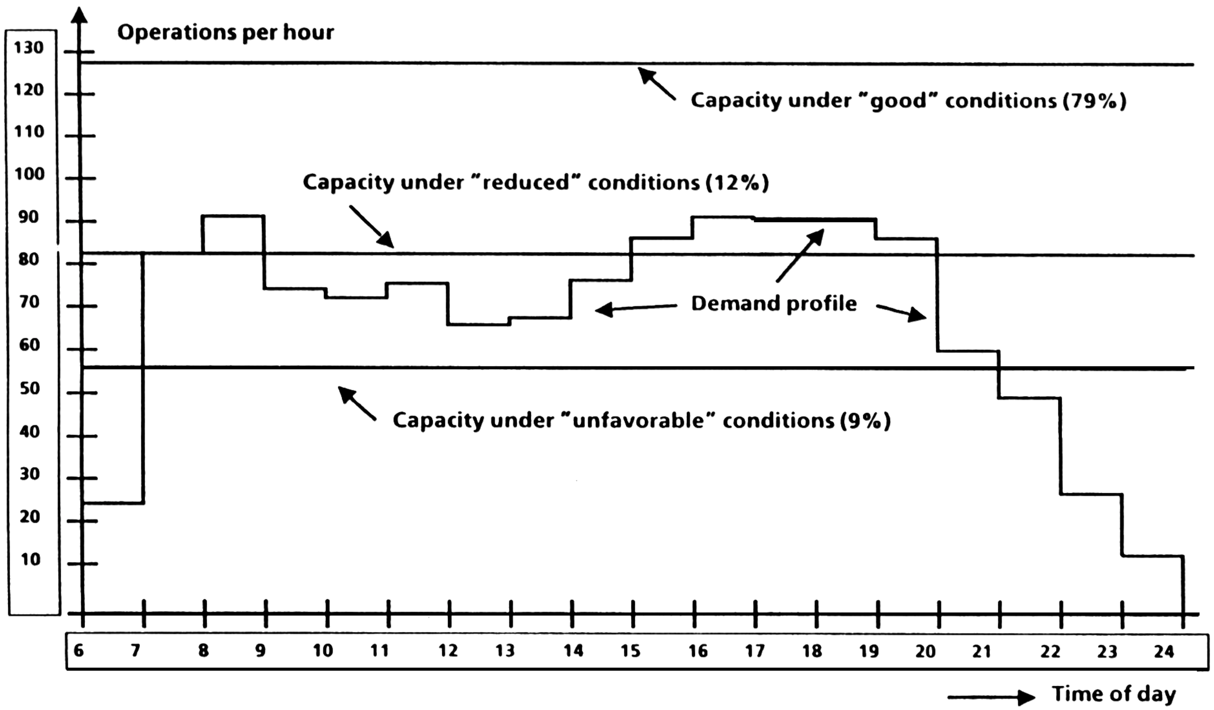
BOS Queuing Model
27/22L-22R Configuration



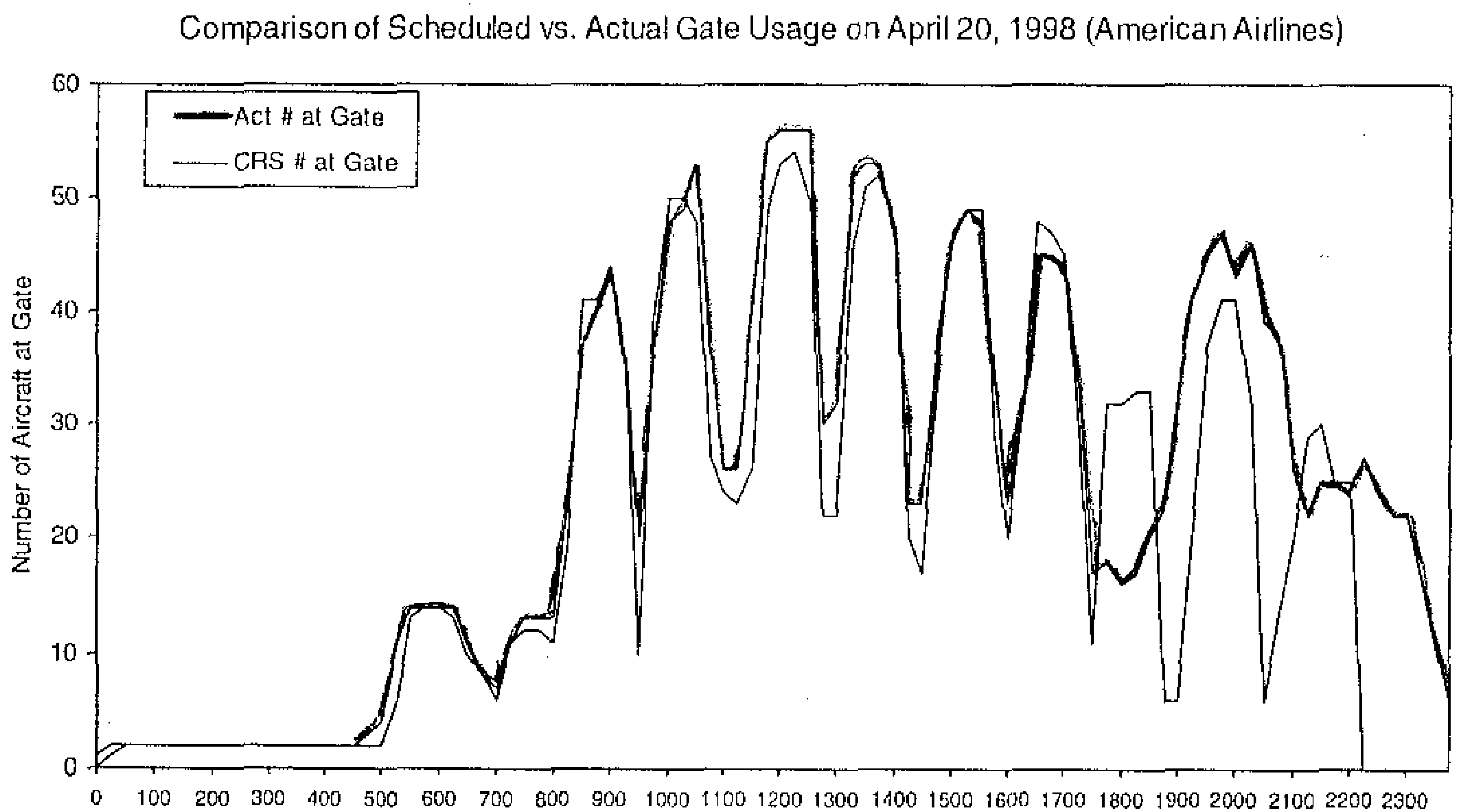
Runway Configuration Capacity Envelops



Demand vs. Capacity at Logan Airport (1987)



The Impact of Delays on Gate Congestion



- Gate congestion was above scheduled at the end of the day due to an apparent missed arrival wave around 1730
- Not only was the peak higher, but it was sustained for a longer period of time

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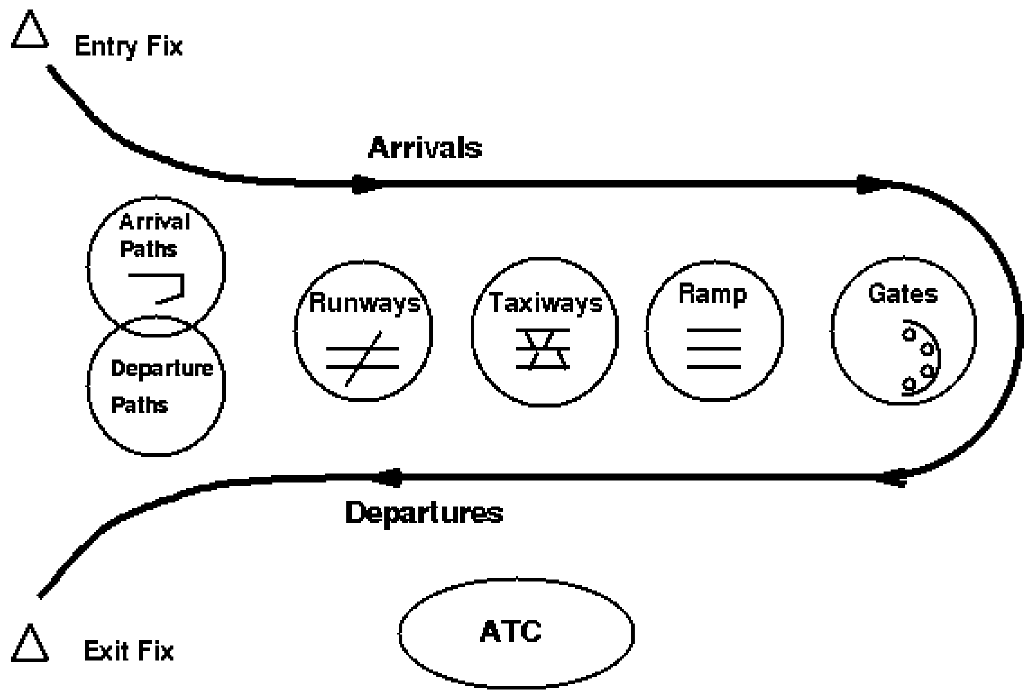
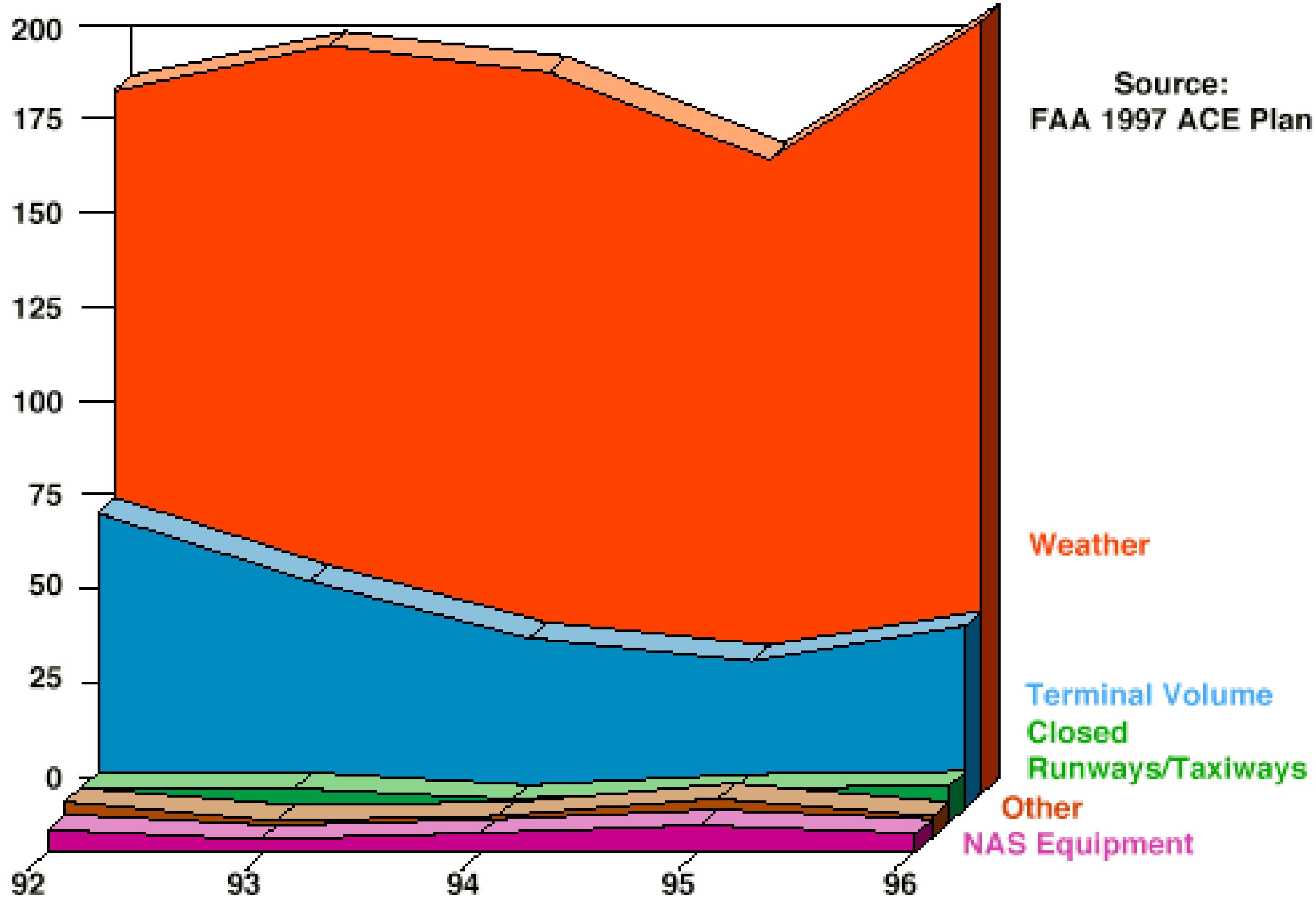


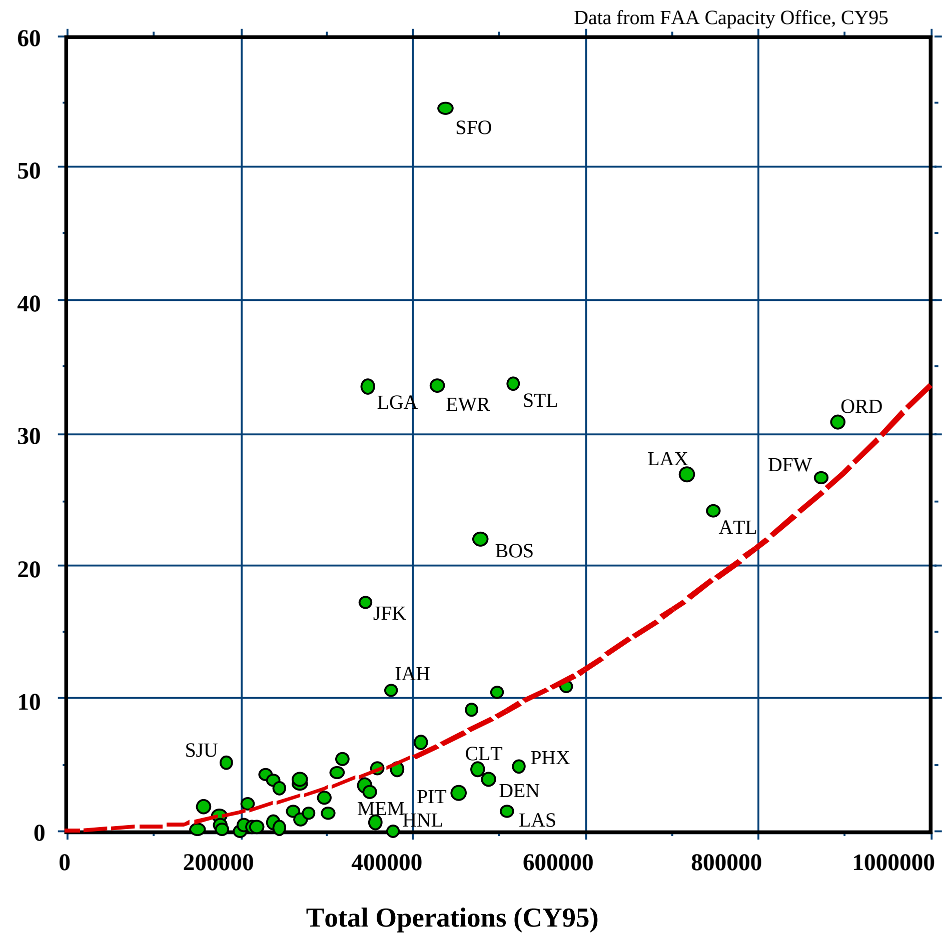
Air Traffic Delays in Thousands

Distribution of Delay Greater than 15 Minutes by Cause



Variable Capacity Effects

1995 Delays vs Operations



From John Andrews, MIT Lincoln Lab

Weather Factors

- **IMC/VMC Capacity Variability**
  - Ceiling and Visibility
    - Start Time
    - Finish Time
- **Convective Weather**
  - Airport
  - Arrival/Departure Gates
- **Windshear**
- **Wind**
  - Runway Configuration
- **Precipitation**
  - Breaking Action
  - Plowing

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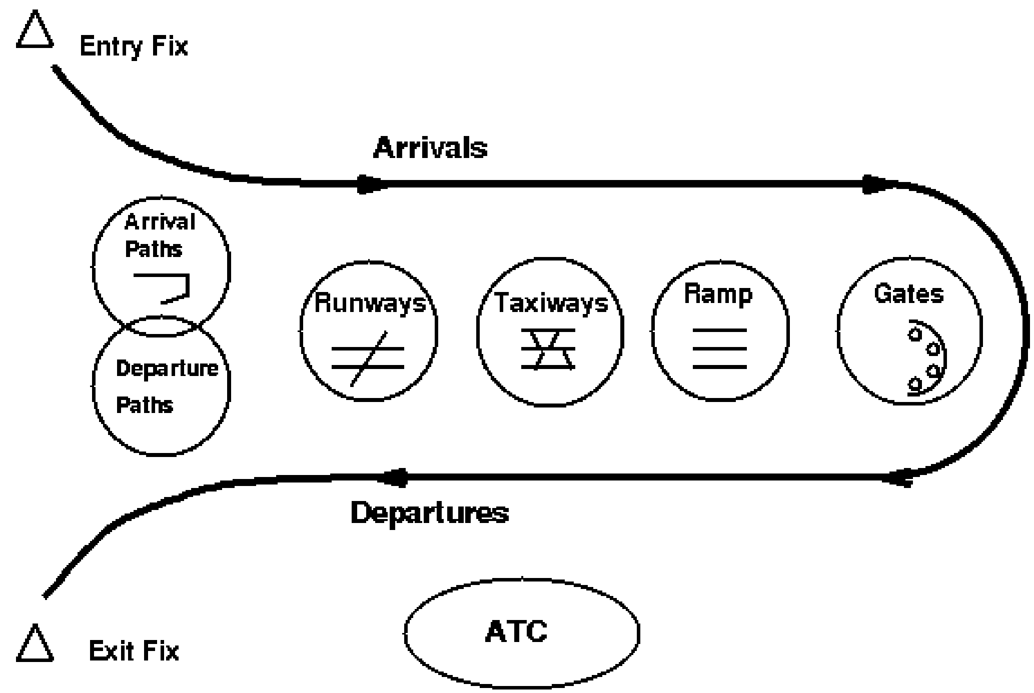
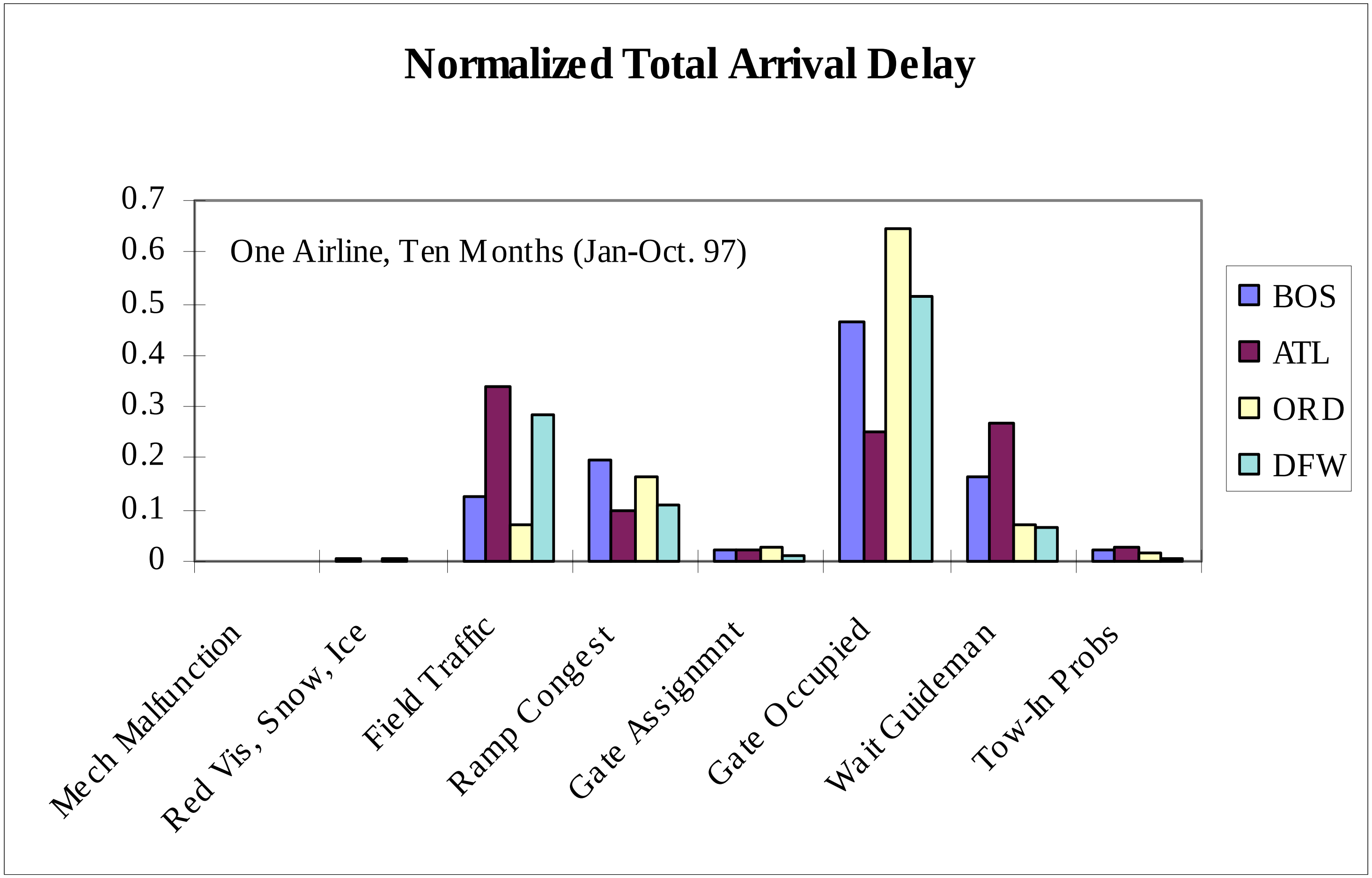
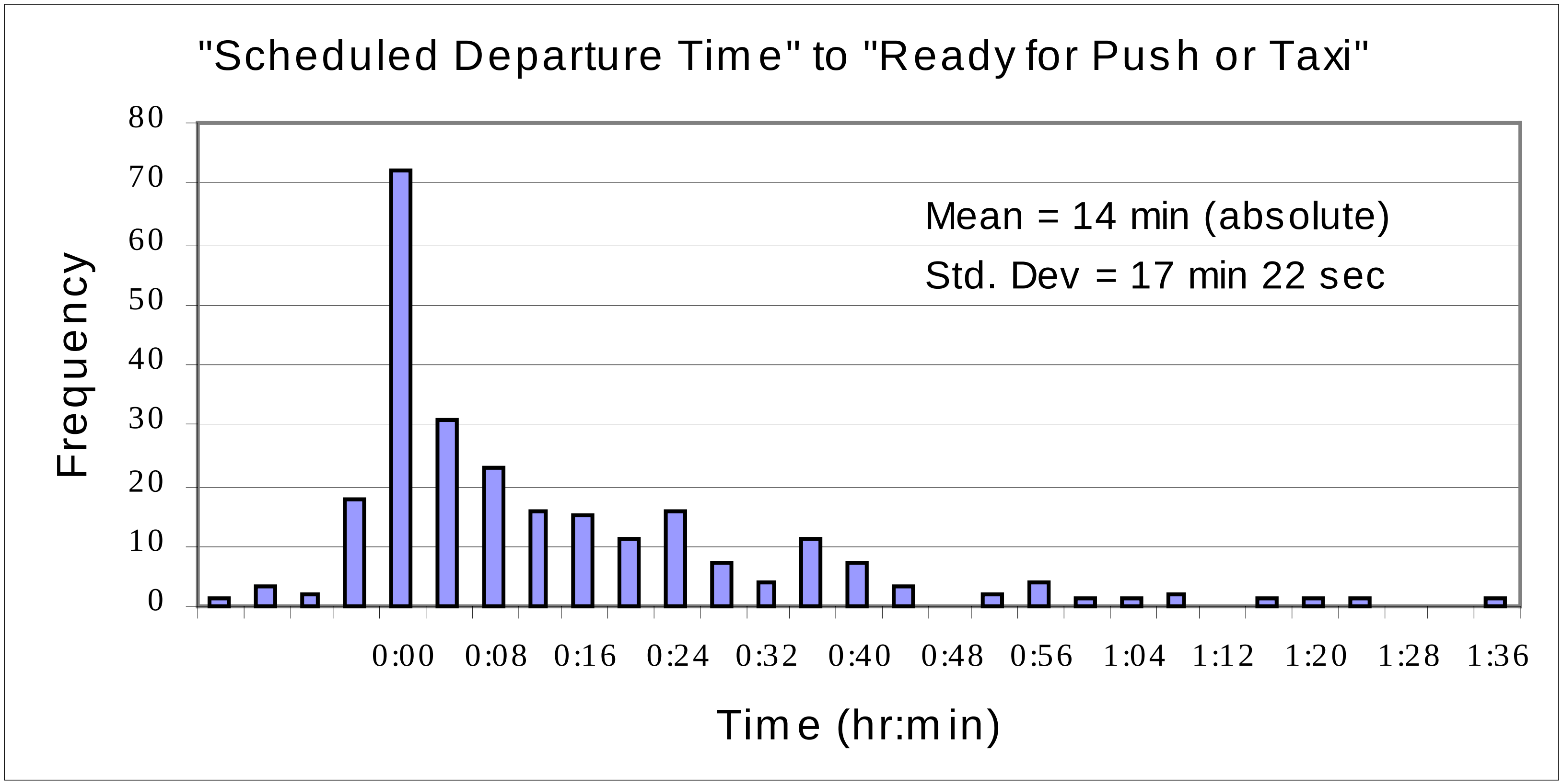


ACARS Constraint Analysis (Arrival)

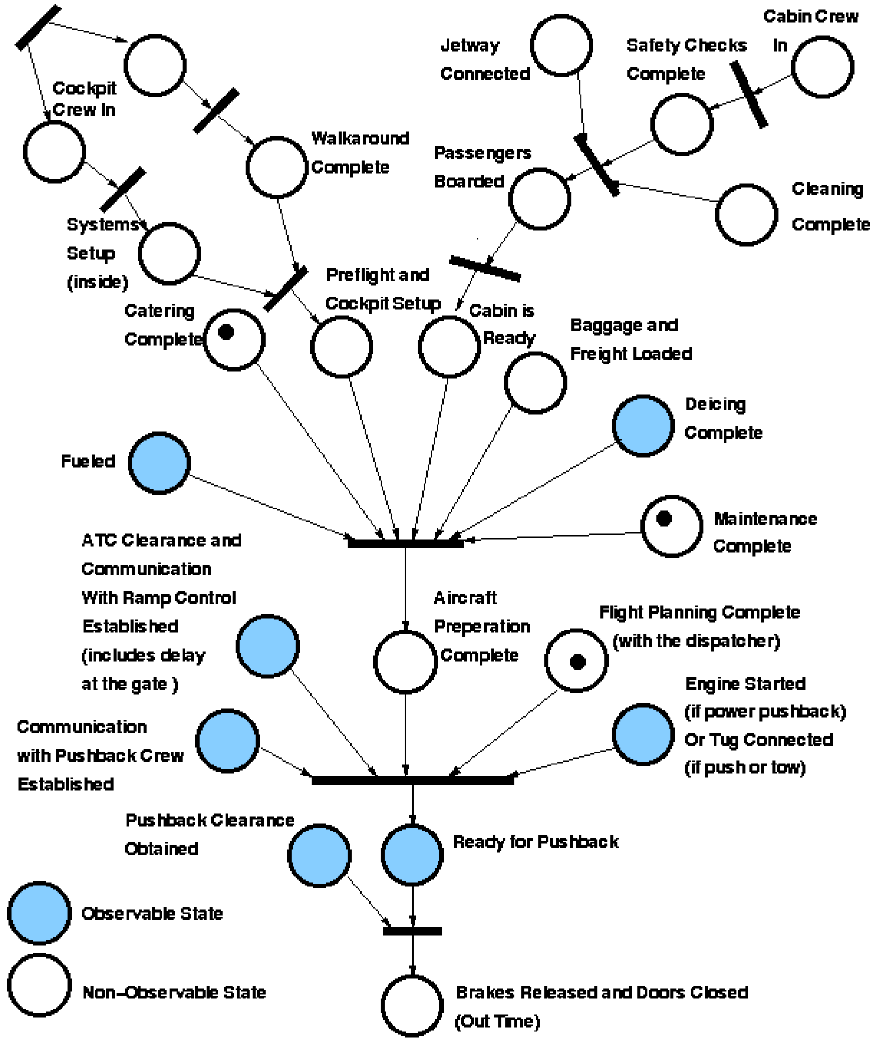


Gate Dynamics

Low Predictability of Departure Demand based on Schedule



On Gate Departure Preparation



Petri Net Analysis

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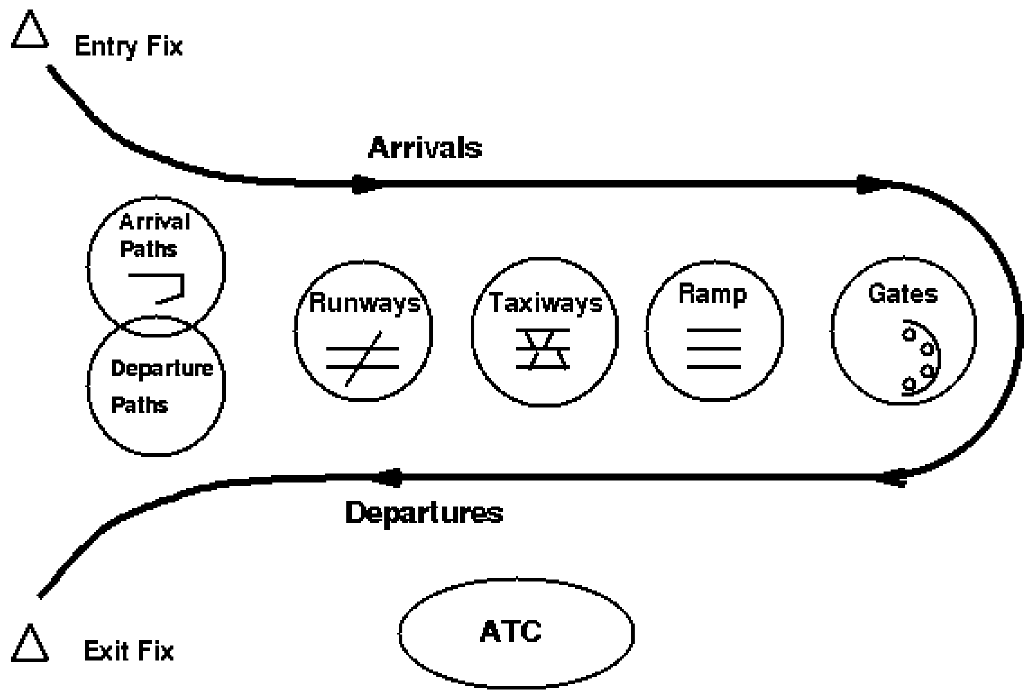
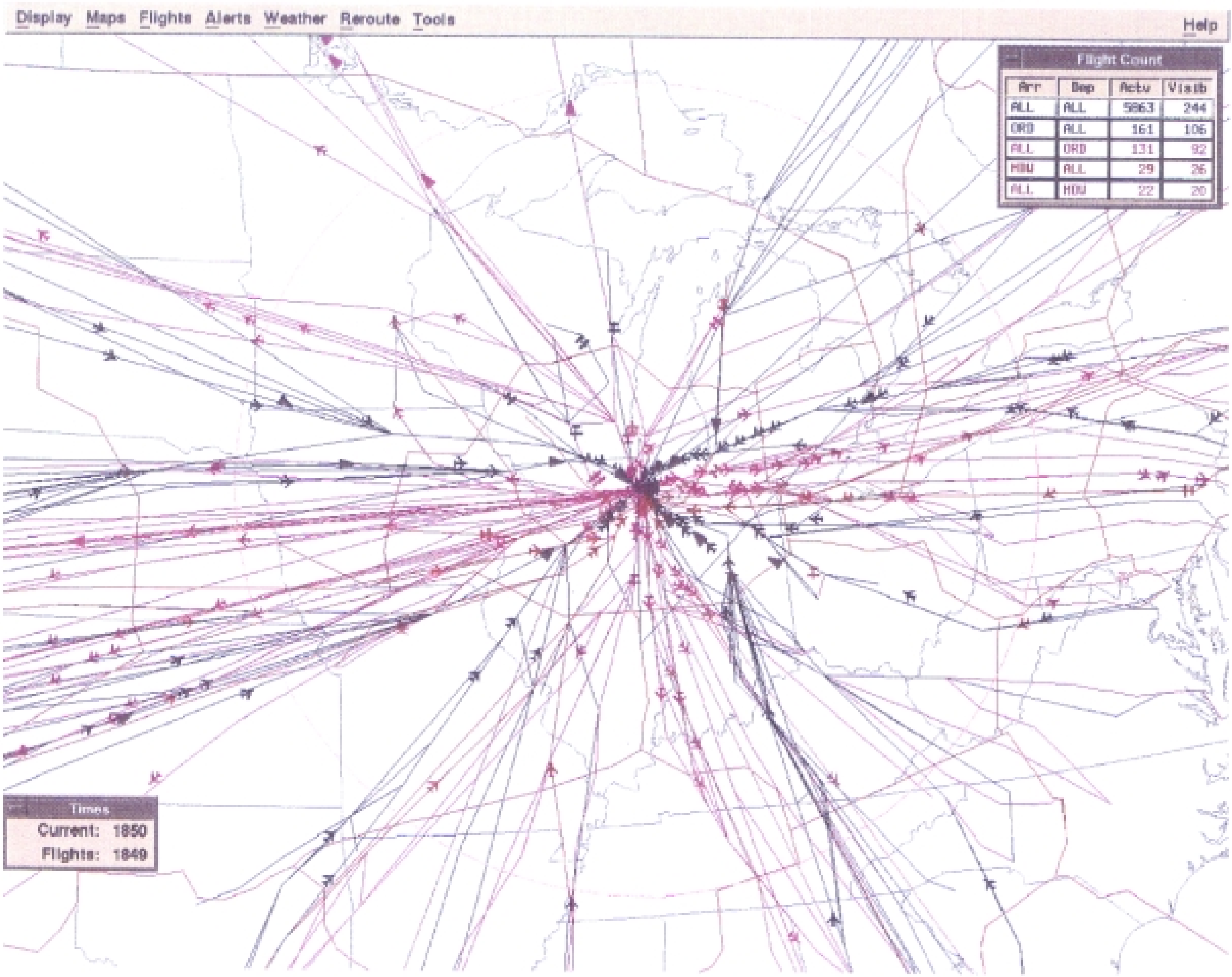
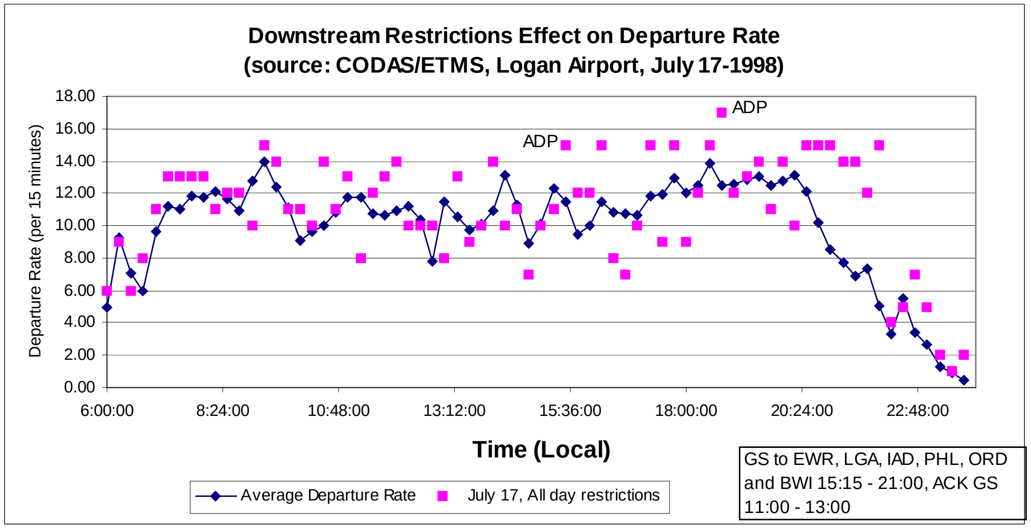
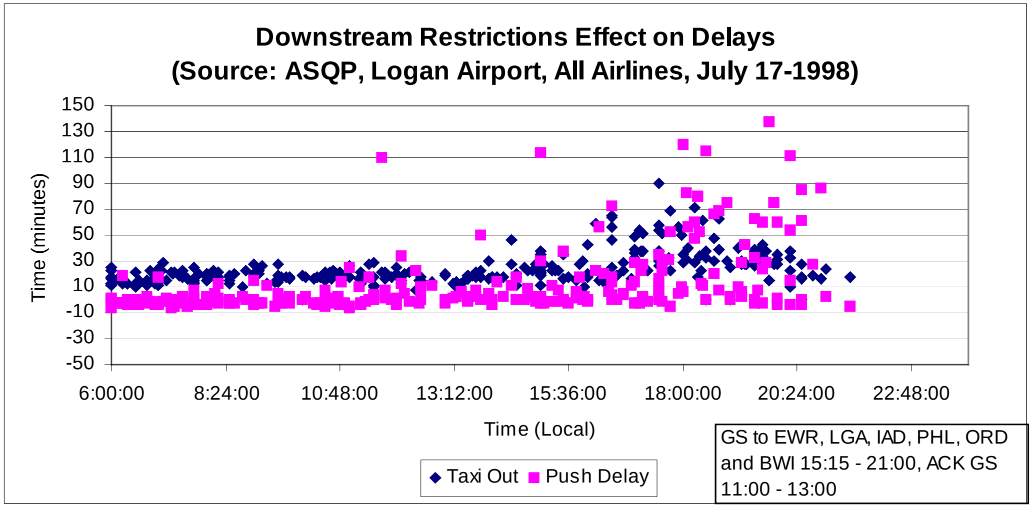




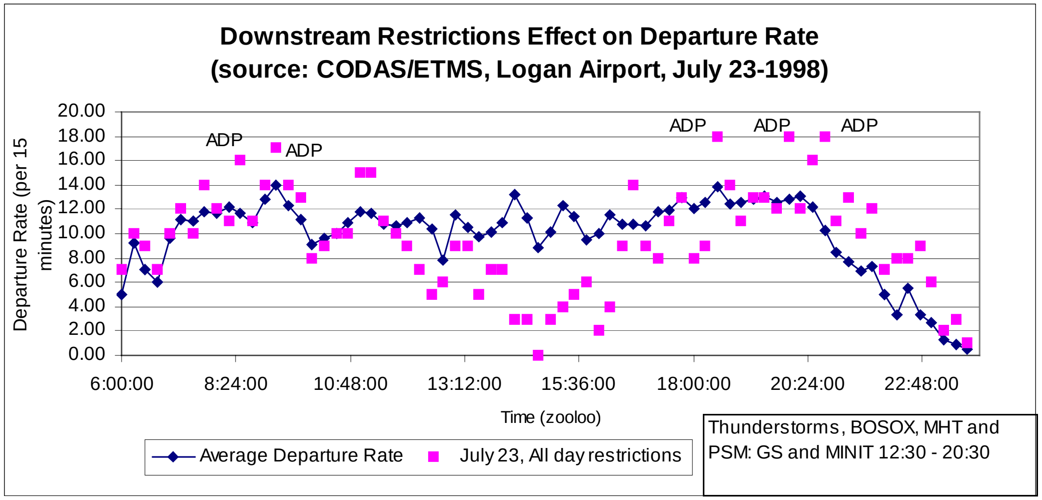
Display
Maps
Flights
Alerts
Weather
Reroute
Tools
Help
Flight Count
Arr
Dep
Actv
Visib
ALL ALL 5863 244
ORD ALL 161 106
ALL ORD 131 92
MDW ALL 29 26
ALL MDW 22 20
Times
Current: 1850
Flights: 1849

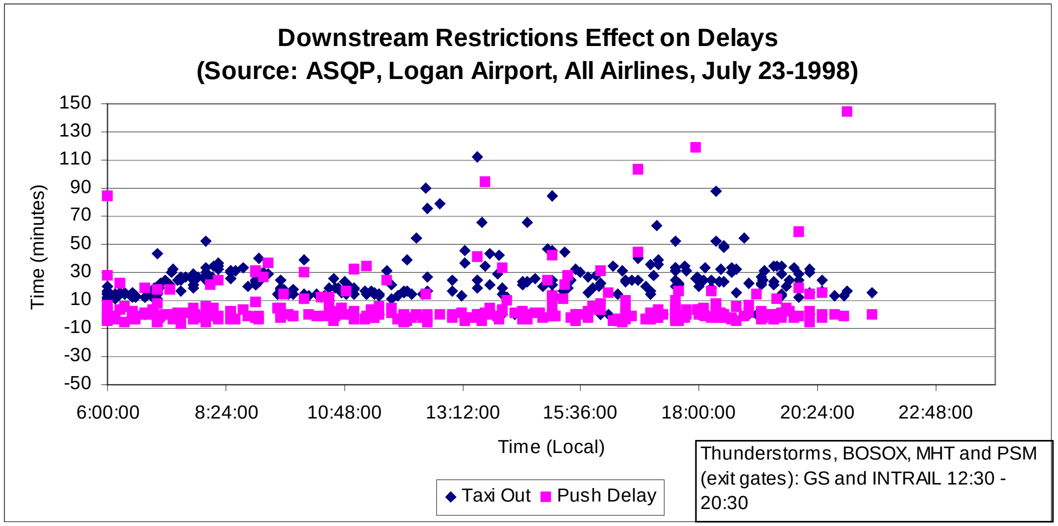
Downstream Restrictions Ground Stops





Downstream Restrictions Local Departure Fix (MHT)





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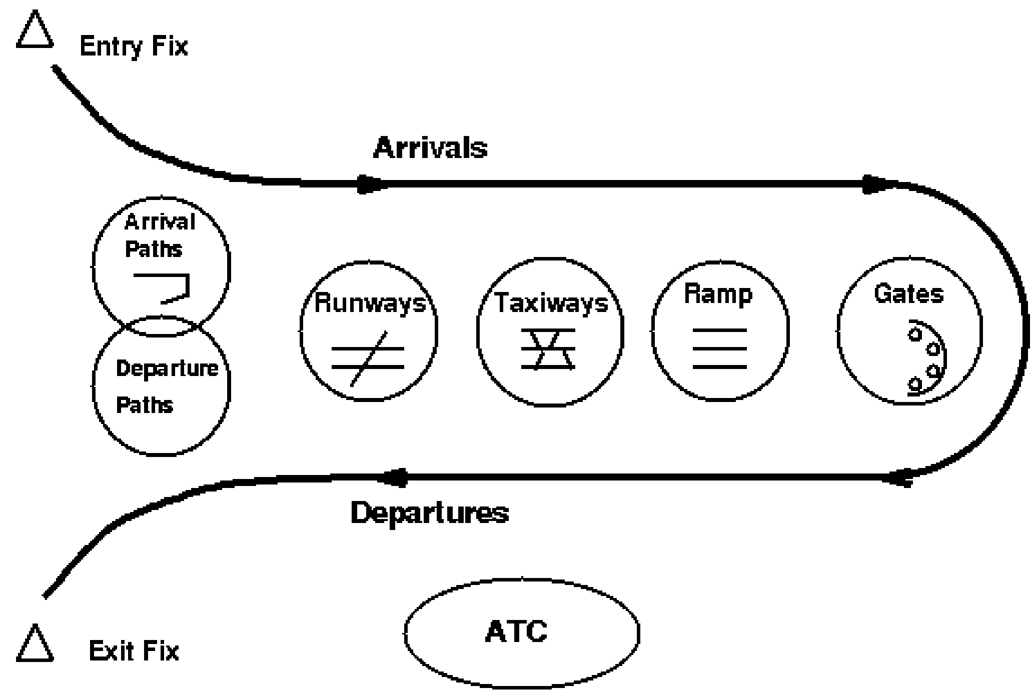
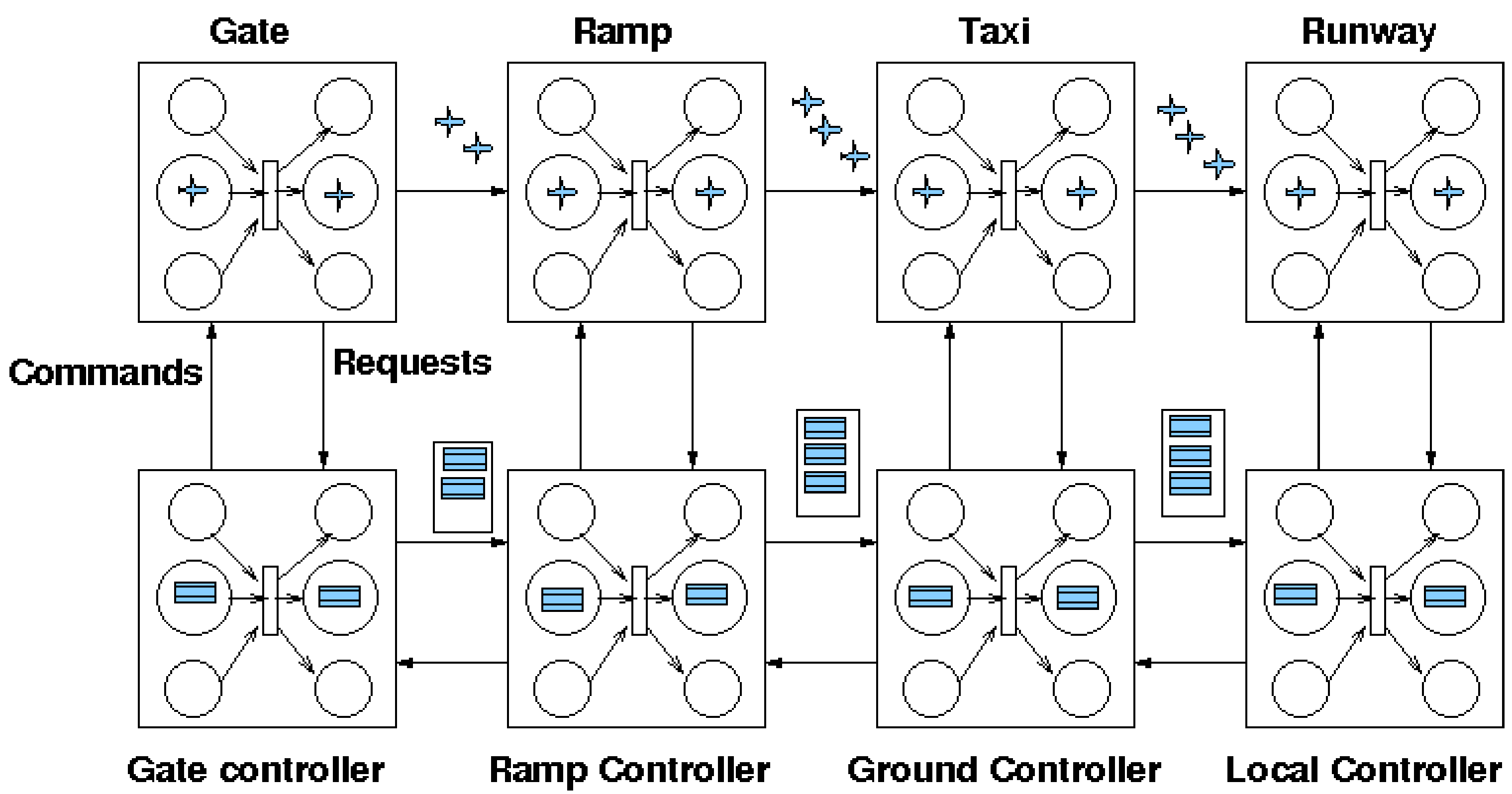


ATC Workload as a System Constraint



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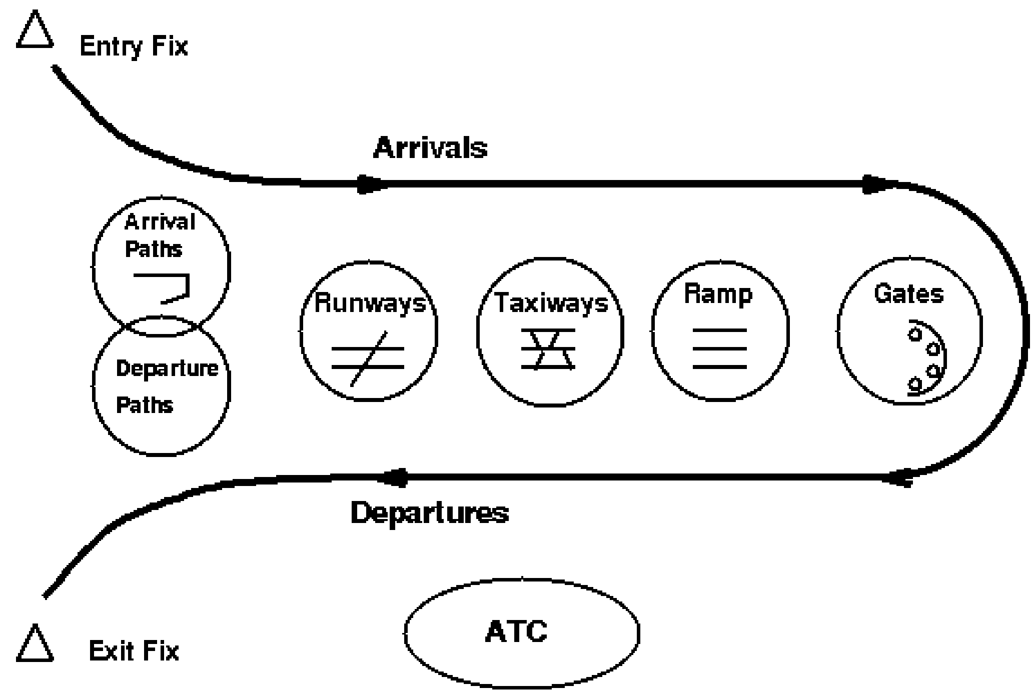

Landside Limits

- **Passenger System Throughput**
- **Road Access Limits**
  - ☐ 1000 Originating Seats/15 min/Terminal
  - ☐ Parking
- **Security Throughput**
  - ☐ Passengers
  - ☐ Baggage (x 20)

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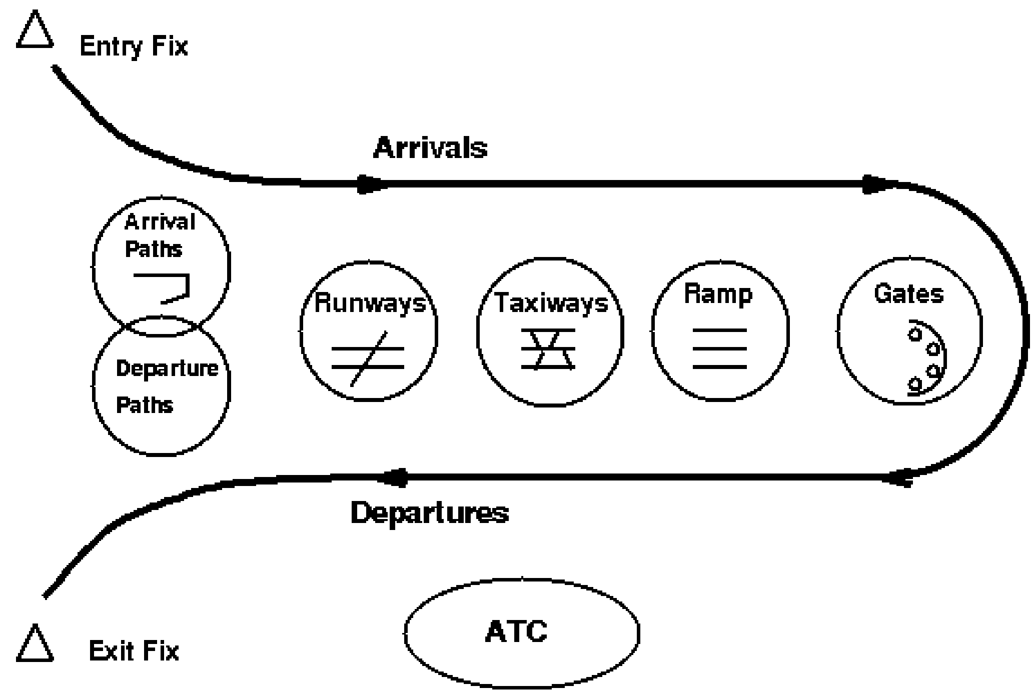
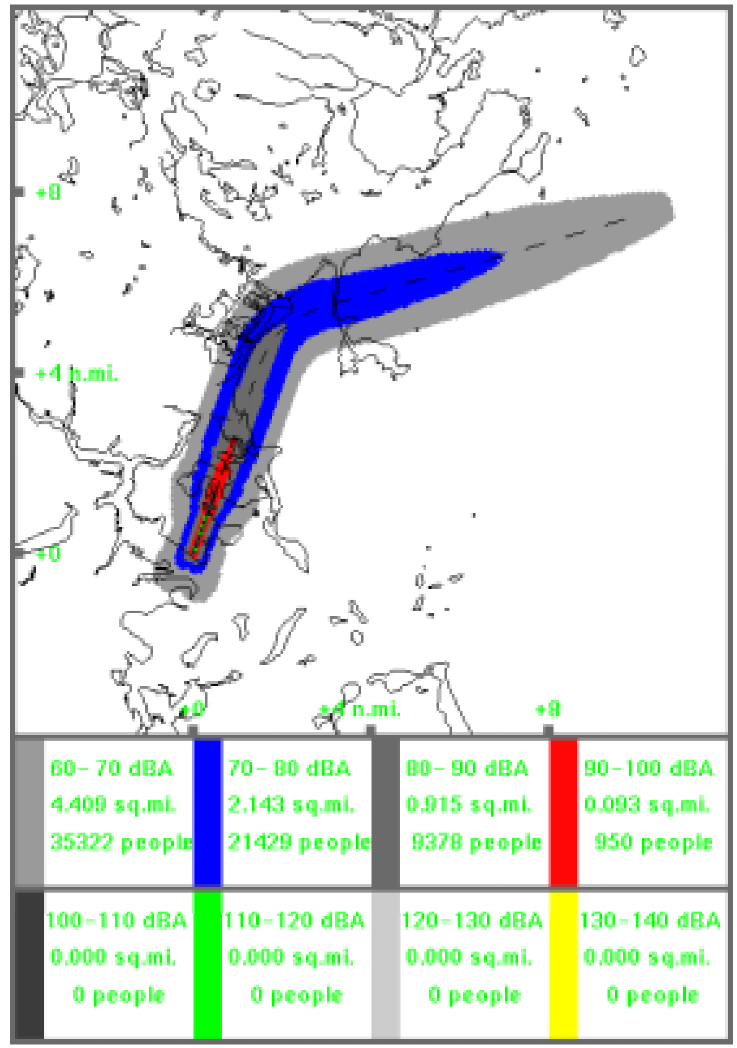


Community Noise Impact

- **Example: Louisville Runway**
  - ☐ 30 > 70 ops/hr
  - ☐ Runway
    - ◆ $447 M
  - ☐ Property within 65 DNL
    - ◆ $350 M



BOS (4R Departure)

Runway Departure Queue Costs Boston, Logan Airport

- The estimated runway queueing time translates into:
  - $ 6.1 million in Direct Operating Costs,
  - significant pollutant emissions:
    - 28 tons of HC,
    - 136.4 tons of CO,
    - 22.0 tons of NO_x .
- Pollutant emissions from runway queueing are equivalent to between 9,440 and 22,330 cars visiting the airport every day.

Pollutant	Runway queue Emissions per year	Equivalent car miles per year	Equivalent car round trips per day
HC	28.0 tons	9.7 million	14,710
CO	136.4 tons	6.2 million	9,440
NO_x	22.0 tons	14.7 million	22,330

Table 6: Environmental impact of current runway queueing.

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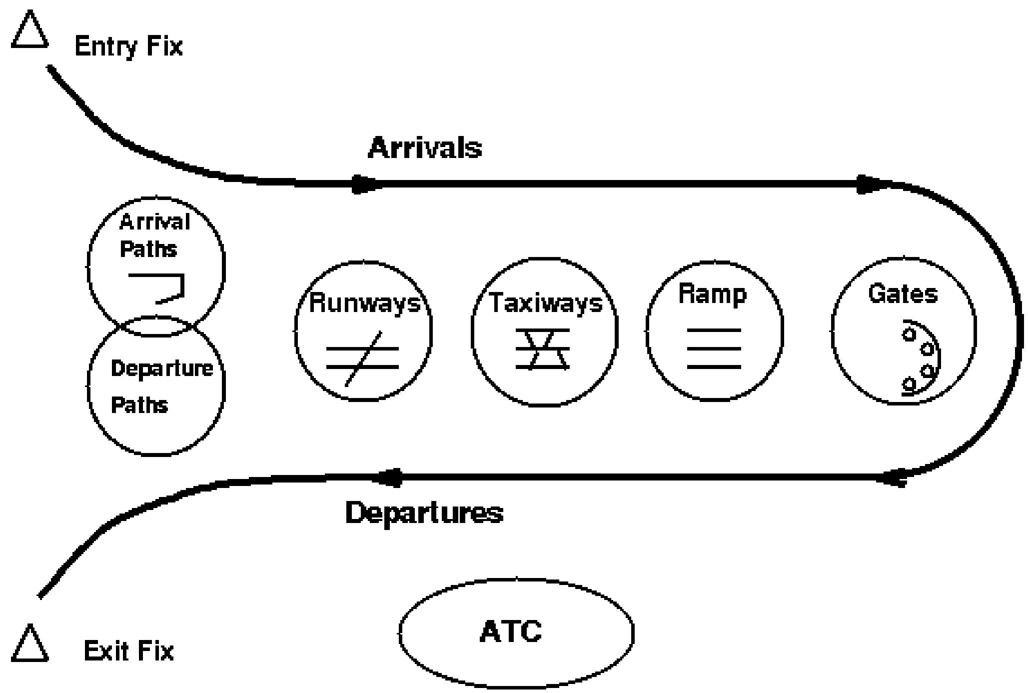
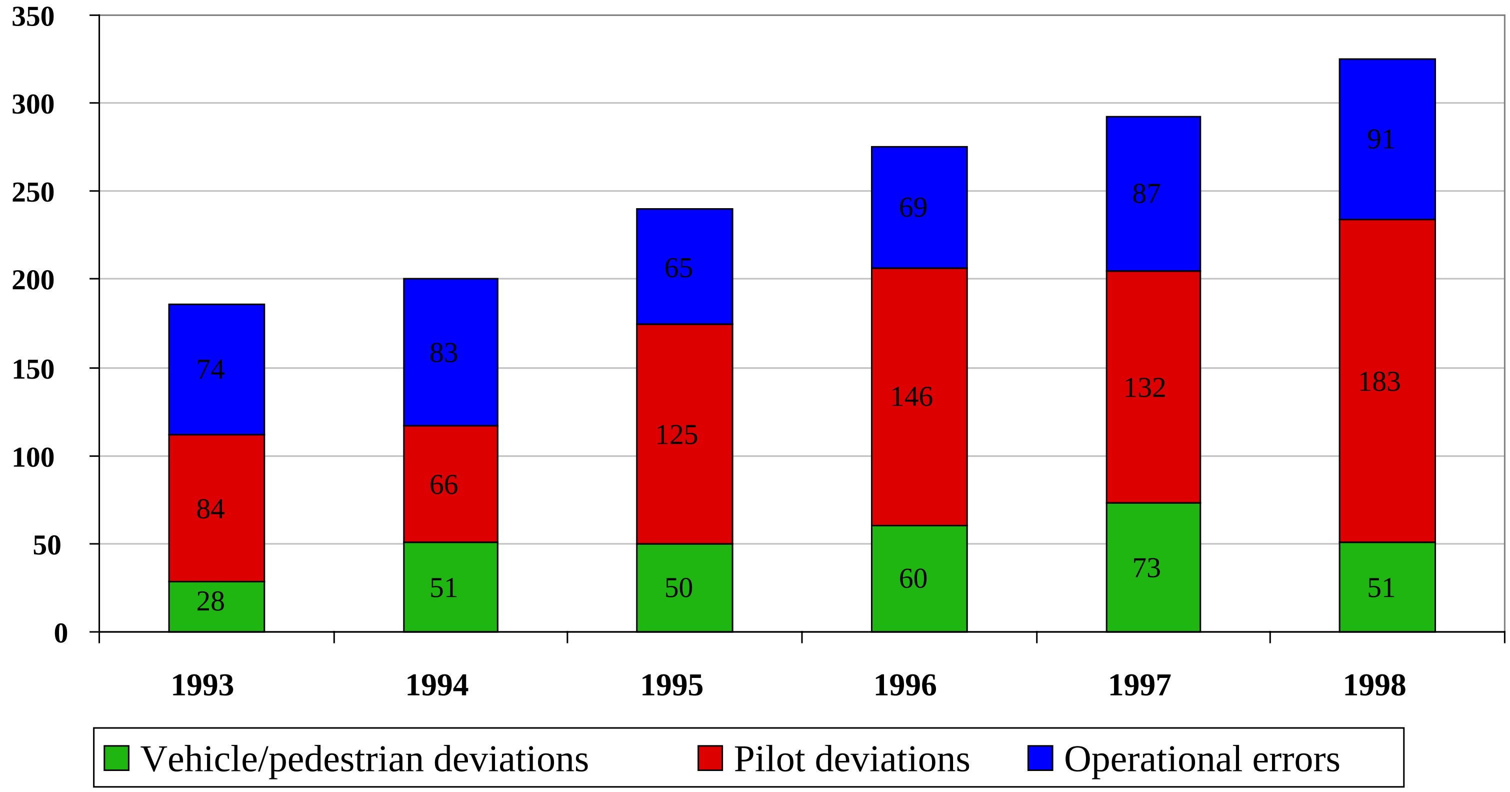


Safety vs Capacity

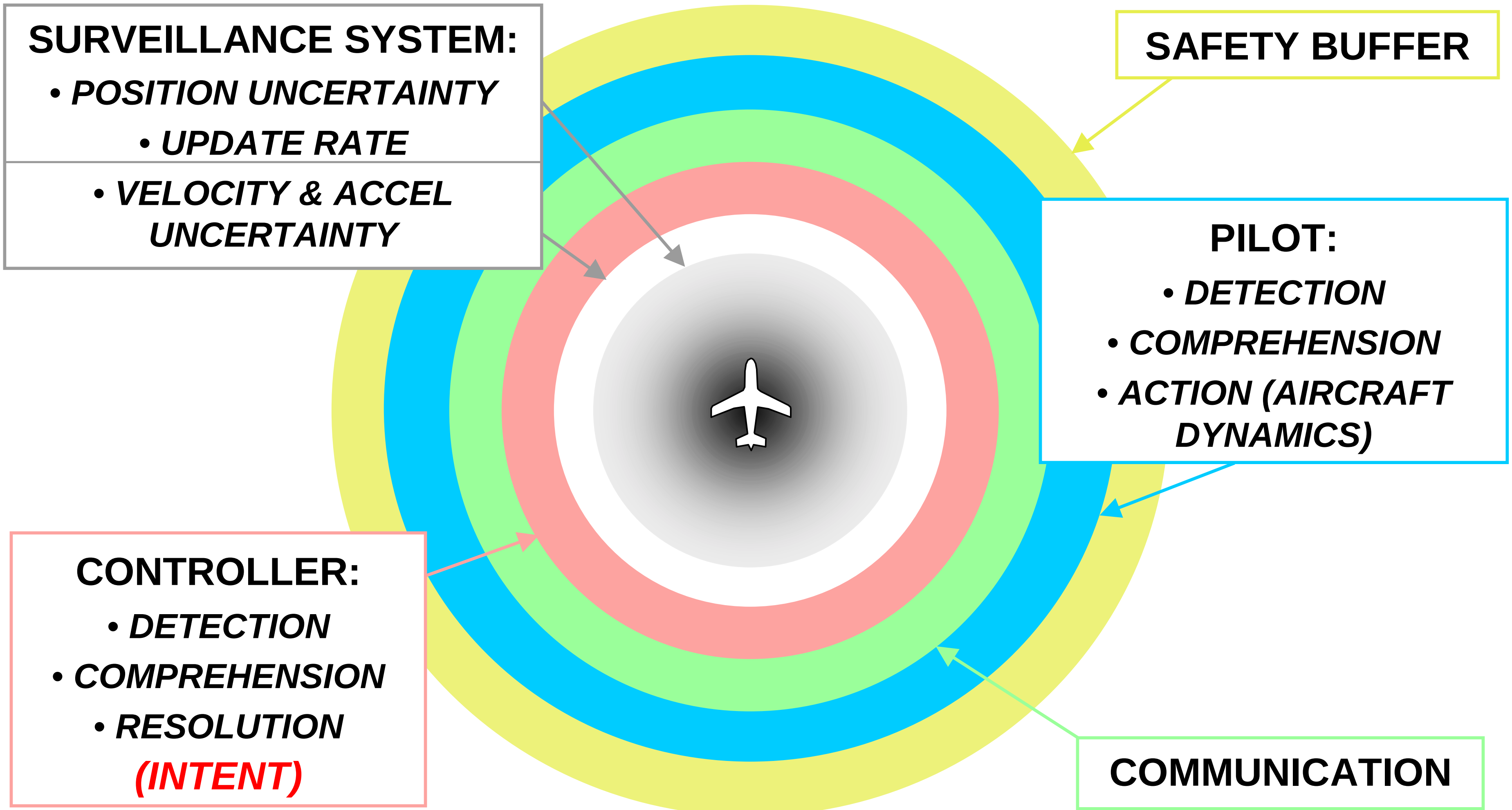
- **The current airborne system is extremely safe but conservative**
- **Runway Incursions are an area of concern**
- **Increased capacity with current infrastructure implies Reduced Operational Separation**
  - Airborne Separation Standards
  - Runway Occupancy Times
  - Wake Vortex
  - Controller Personal Buffers
  - ...
- **How do you dependably predict the safety impact of changes in a complex interdependent system?**
  - Statistics of small numbers
  - Differential analysis limited to small or isolated changes
  - Models??
- **Safety Veto Effect**

RUNWAY INCURSION STATISTICS



Source: FAA

SEPARATION ASSURANCE BUDGET COMPONENTS



NOTE: budget components not to scale (relative sizes have changed over time)

Potential Technology Impact
Examples

- **Runway Efficiency, Reduced Volatility**
  - ☐ Single Stream Compression
  - ☐ Close Parallel Approach
  - ☐ Wake Vortex Sensing (Dynamic)
  - ☐ Pairwize Self Separation
  - ☐ VFR Performance in IFR
- **Terminal Area Efficiency**
  - ☐ Flow to Final
  - ☐ Load Balancing
  - ☐ Multi-Runway Coordination
- **More Efficient Use of Resources (Systemwide and Local)**
  - ☐ Collaborative Decision Making
  - ☐ Information Sharing
  - ☐ Wx Prediction
- **Environmental Benefits**
  - ☐ Minimal Noise Procedures
  - ☐ Minimal Surface Runtime/Emissions

ATM Technology Components

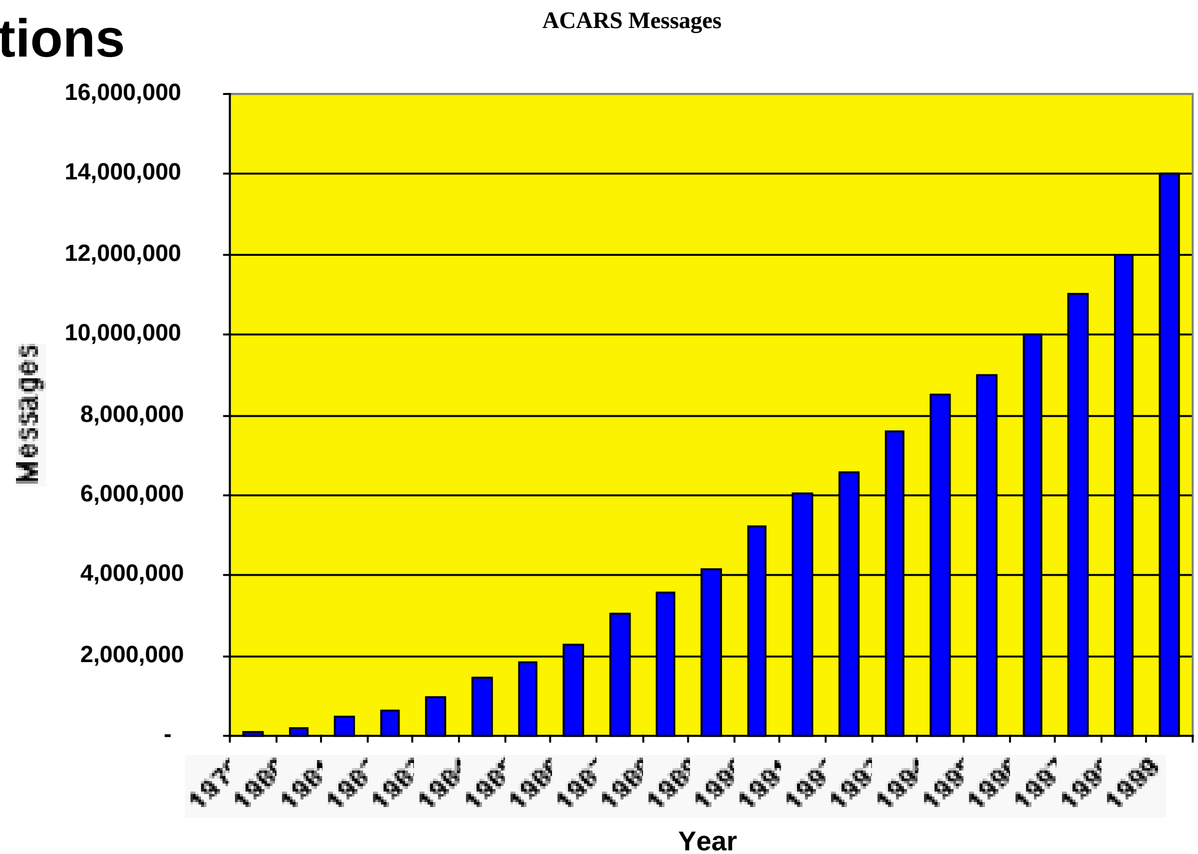
- **Physical Infrastructure**
  - ☐ Runways
  - ☐ Gates
  - ☐ Terminals
  - ☐ Landside
- **Communication**
- **Navigation**
- **Surveillance**
- **Information Architecture**
  - ☐ Information Sharing Tools
  - ☐ Decision Support
  - ☐ Weather
  - ☐ Databases
- **Control Systems/Procedures**

Infrastructure

- **Runways (Concrete)**
  - Marginal Increase in Peak Capacity Available at Existing High Demand Airports (less than 40%)
  - New Runways Politically Difficult
    - Noise
    - Emissions
- **Gates**
- **Terminals**
- **Landside**
- **Direct Impact on Capacity**

Communications

- **Satellite Communications**
- **Datalink**
- **CPDLC**
  - ☐ Latency Problems
    - ◆ Terminal Area
  - ☐ Approach Routing
  - ☐ Taxi Routing
- **ACARS**
  - ☐ PDC Clearance
  - ☐ Airline Coordination

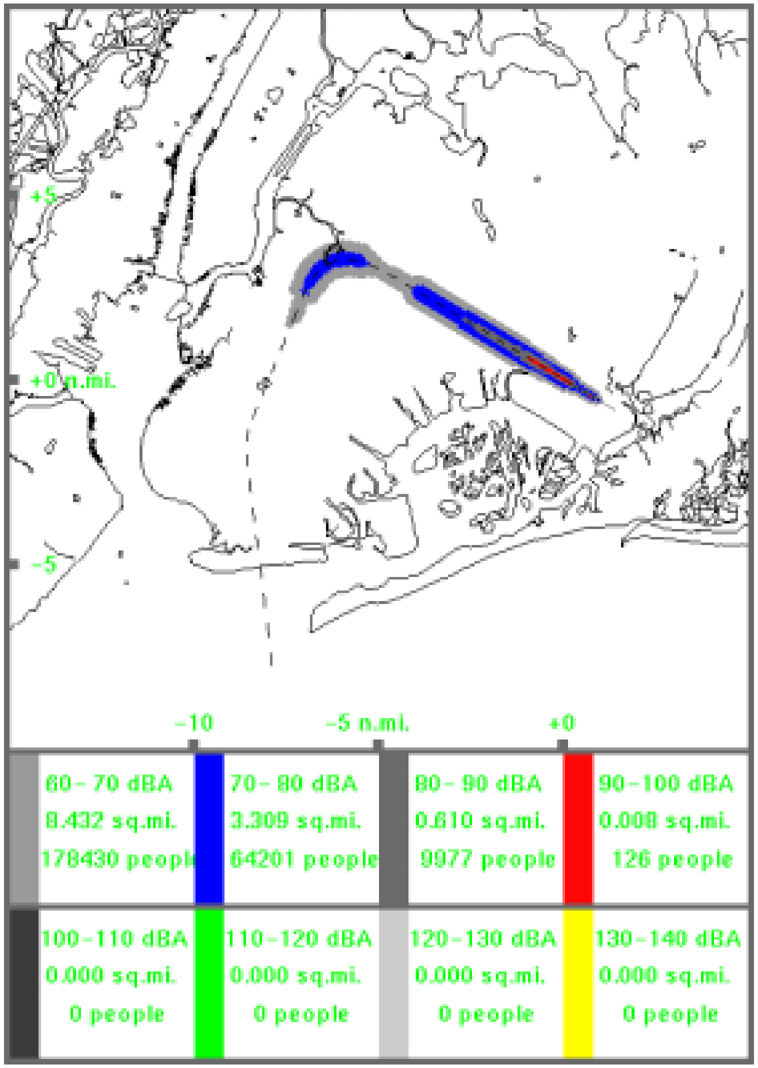


- **Limited direct impact on Airport Capacity**
- **Relives VHF Channel Saturation**

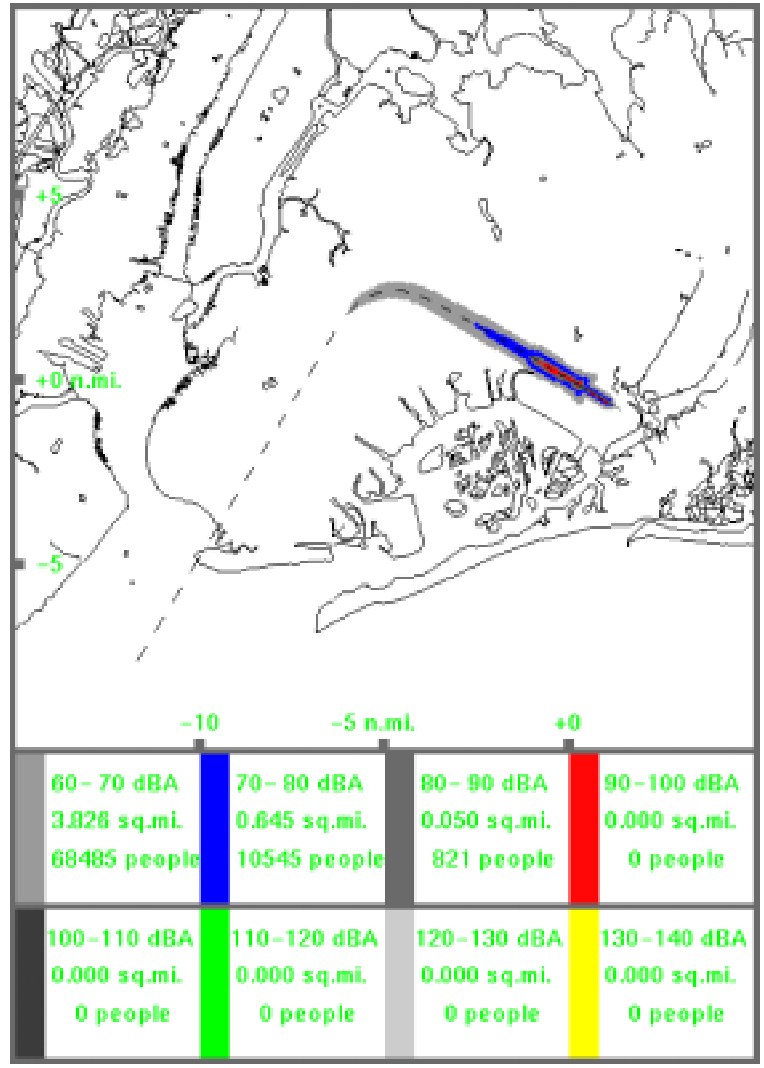
Navigation

- **GPS**
  - Initial Approach (CA)
  - Cat I (WAAS)
  - Cat II, III (LAAS)
  - Surface (WAAS)
- **WAAS**
  - In trouble, integrity Issues
- **LAAS**
  - Carrier Phase
  - Code Based
- **Approach Guidance Potential Benefits**
  - Noise, Close Parallel Approaches
- **Surface Guidance**
- **Issues**
  - Jamming
  - Surveying, TERPS
  - Lighting

3° Decelerating Approach (JFK 13L)



Existing ILS Approach

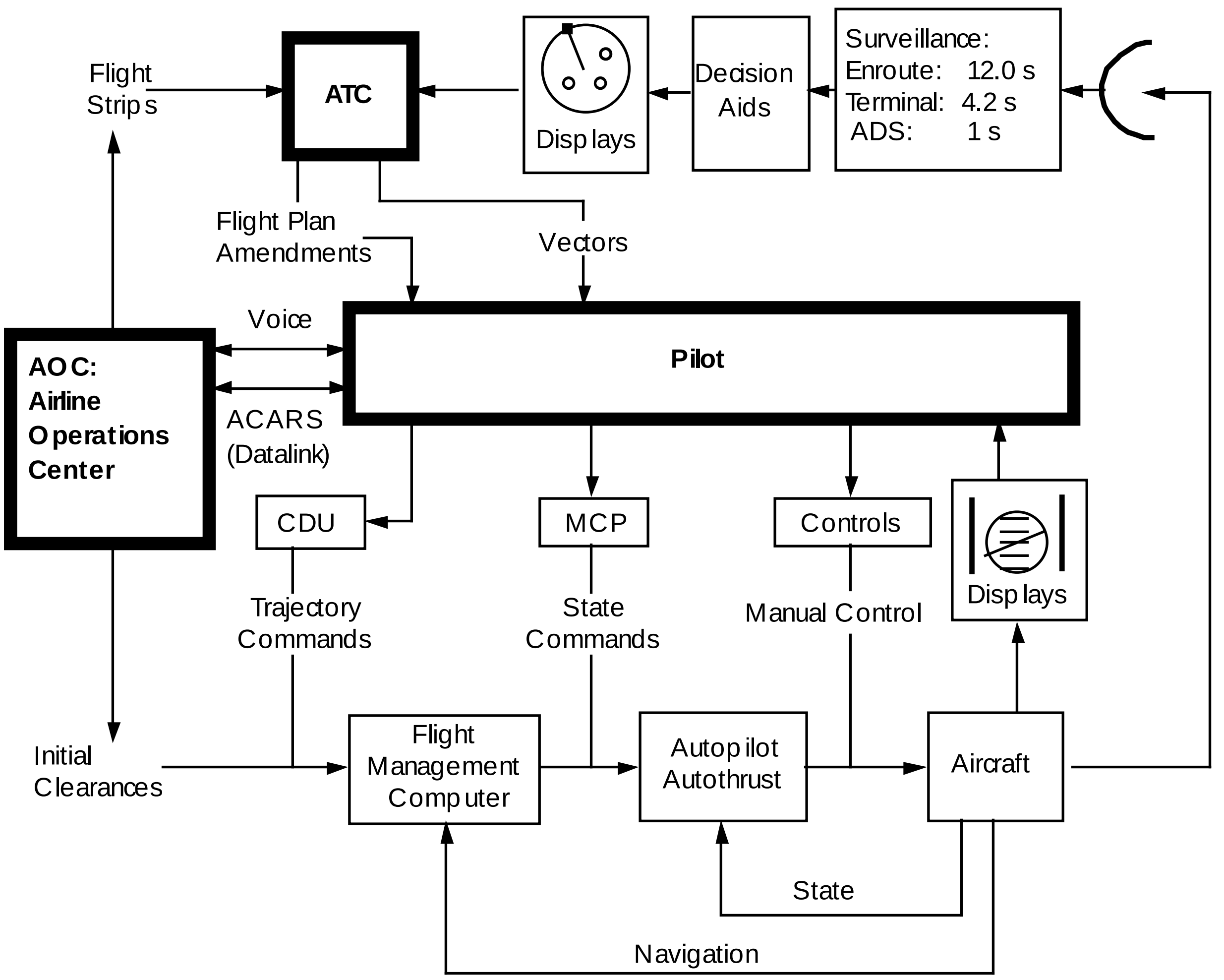


3° Decelerating Approach

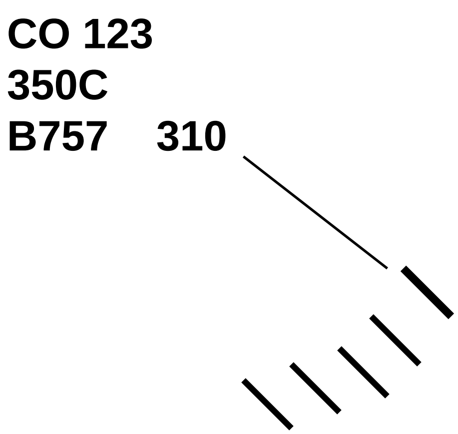
Surveillance

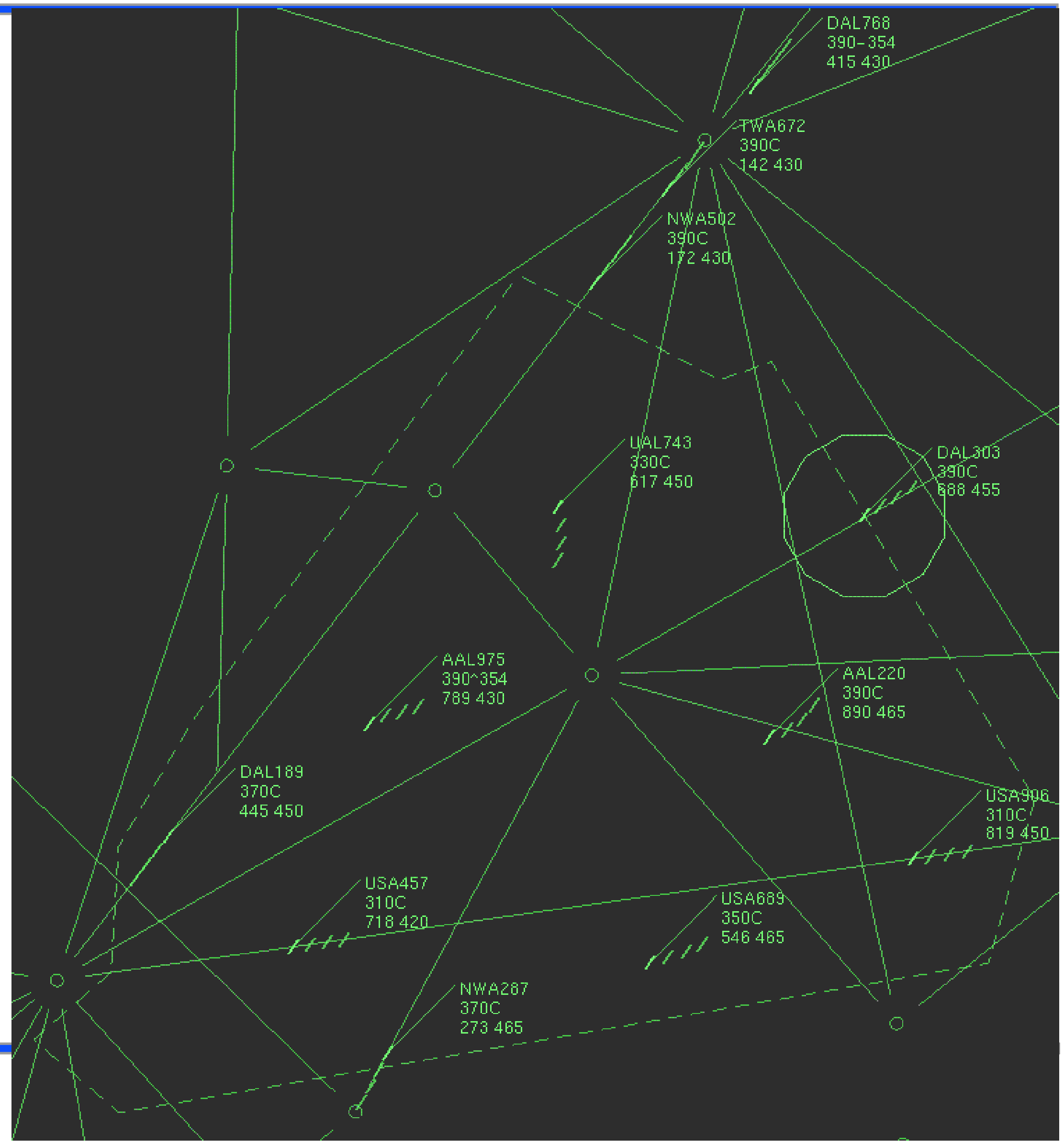
- **Enhanced Digital Radar Performance**
  - Precision, Weather
- **ADS-B (Compression Benefits)**
- **AMSS (Safety, Runway Incursions)**
  - Radar
  - Multilateration
- **AVOSS (Dynamic Vortex Separation)**
- **Synthetic/ Enhanced Vision**
  - Aircraft (VMC Separation in IMC) (Compression)
  - Tower (Safety)
- **Compression Benefits**
  - Tighter Control Loops
  - Close Parallel Approaches
  - Pairwize Self Separation
  - Dynamic Vortex Separation

ATM Basic Control Loops



Radar Display Example

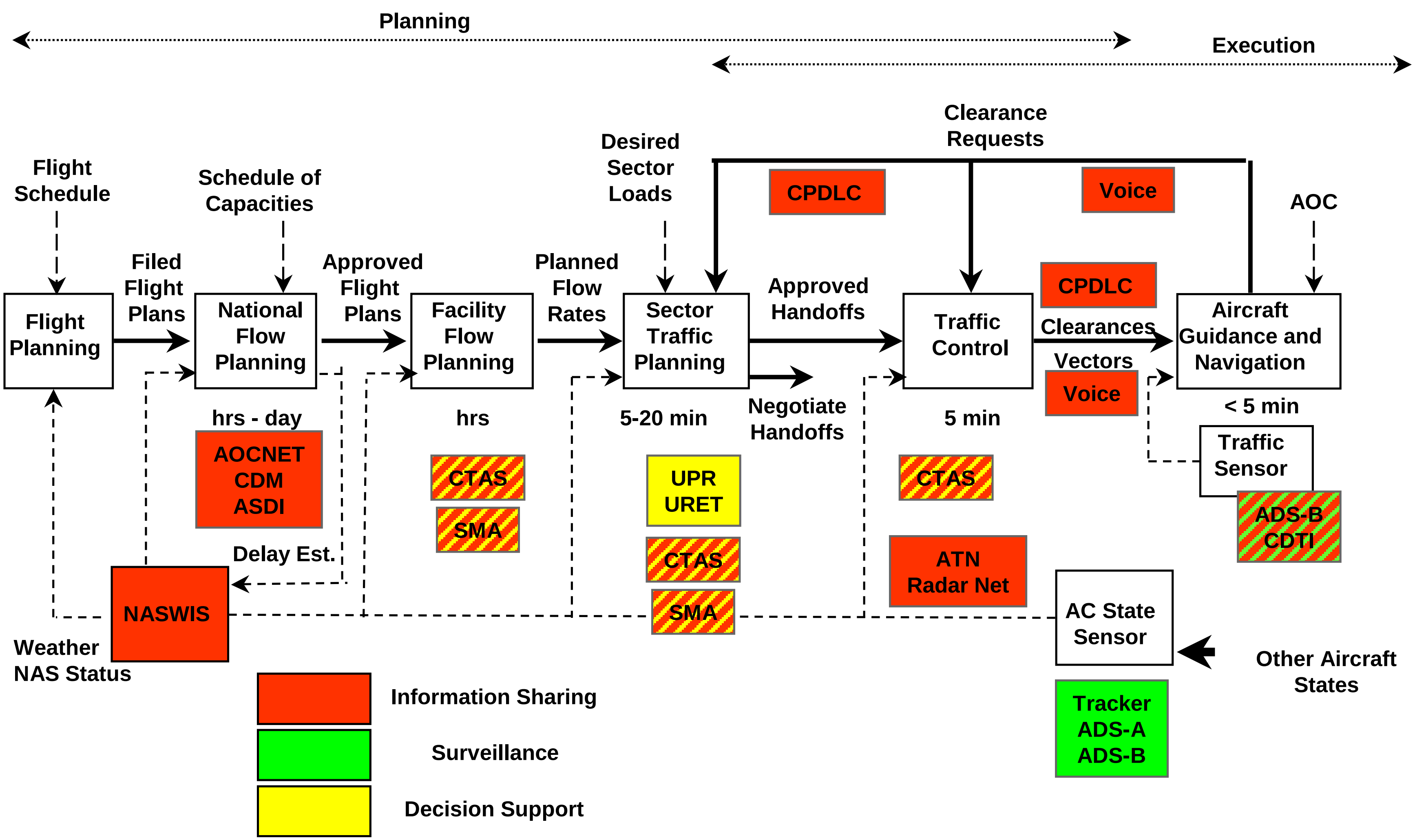




Information Architecture

- **Information Sharing**
  - Collaborative/Informed Decision Making
    - Strategic
    - Tactical
- **Decision Support Tools**
- **Weather**
- **Databases**
- **Improved/Use of Existing Resources**
  - Capacity
  - Predictability, volatility
- **Note: Must consider degraded mode operation**
  - If high Traffic Density or Reduced Separation are Dependant on Surveillance, Navigation, Information Sharing, or Decision Support Tools need recovery strategy for failures.

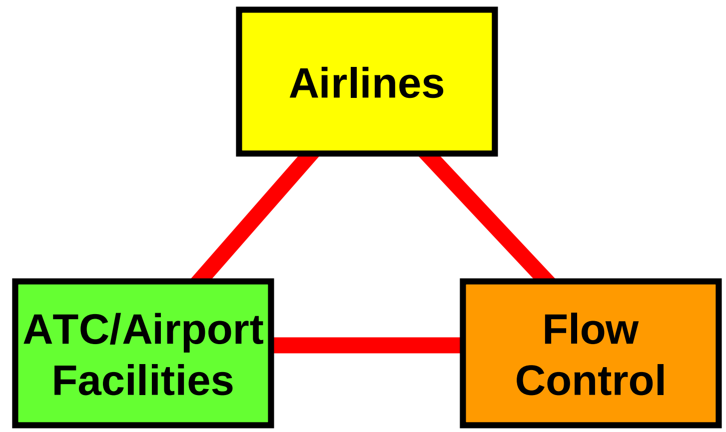
Proposed CNS/ATM Information Technologies



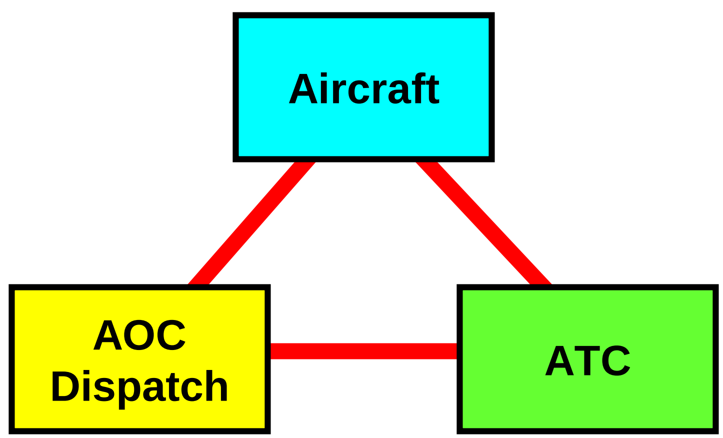
Adapted from; A. Haraldsdottir Boeing

Collaborative Decision Making

- **Strategic Level**
  - ☐ Schedule
  - ☐ Cancellations
  - ☐ Response to Severe Weather
  - ☐ Response to Capacity Restrictions
    - ◆ Airport
    - ◆ Enroute

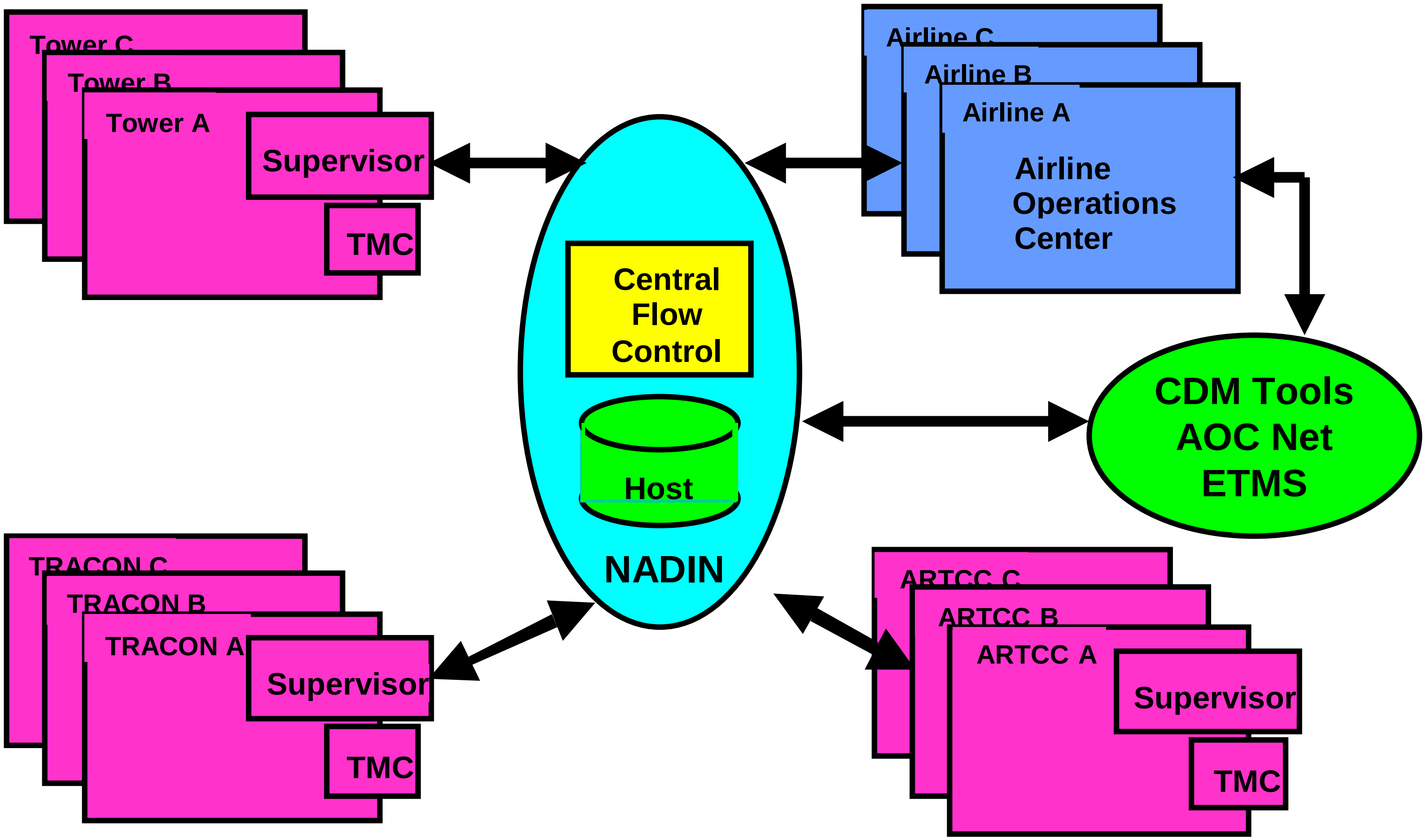


- **Tactical Level**
  - ☐ Diversions
  - ☐ Prioritization
  - ☐ Routing
  - ☐ Sequencing
    - ◆ Arrival
    - ◆ Departure

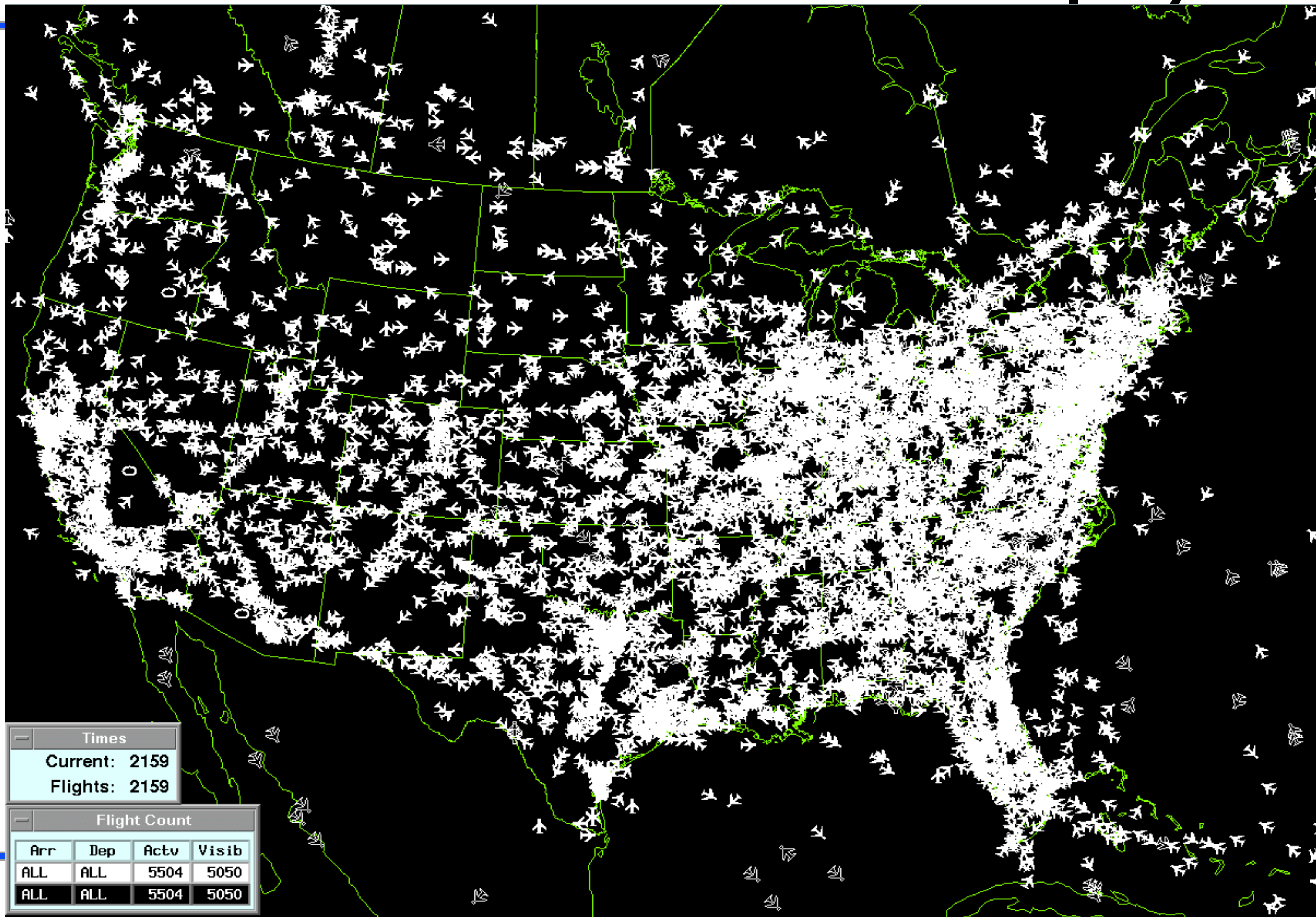


Information Sharing Paths

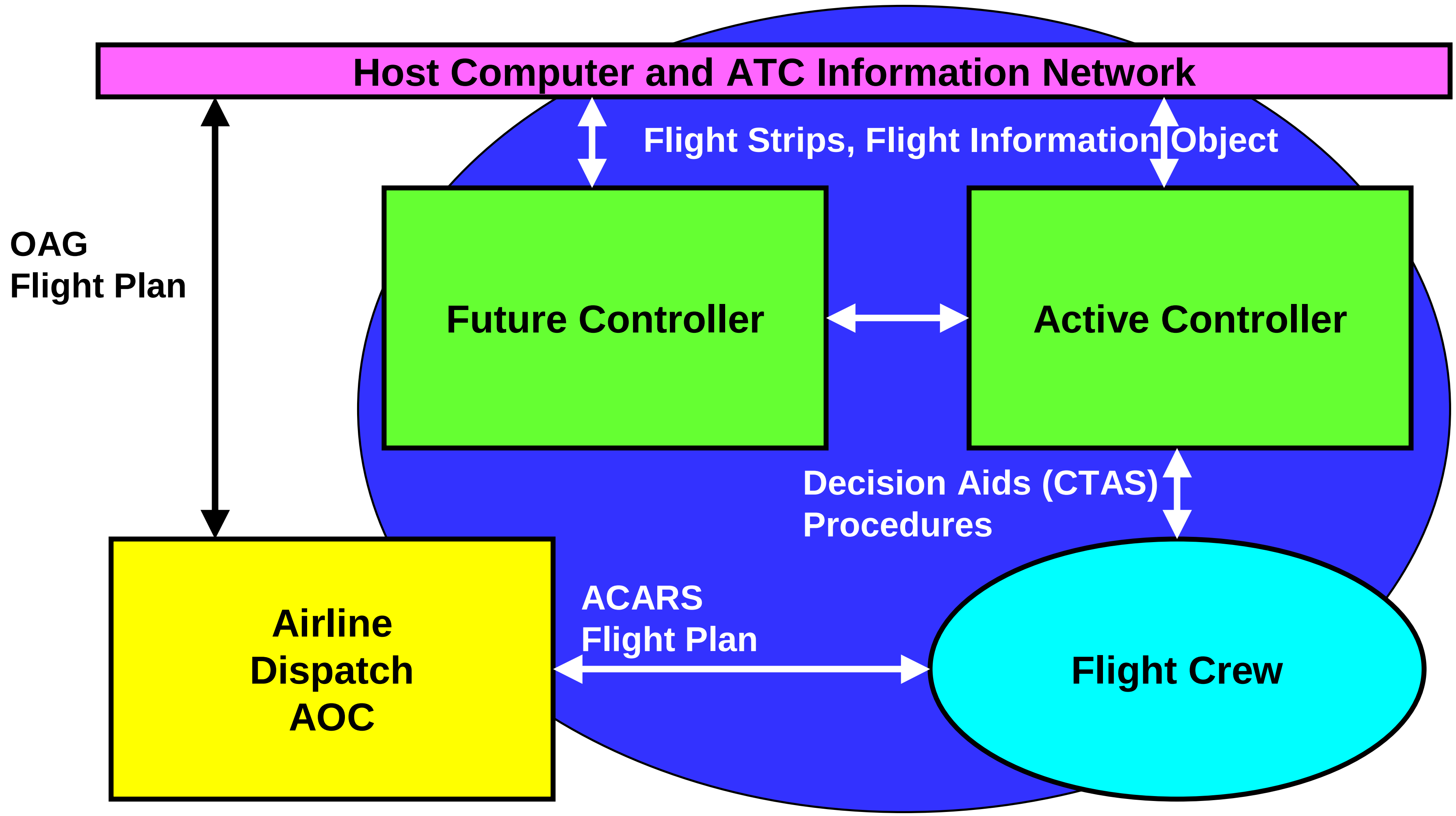
ATM Strategic Information Architecture



ETMS
Traffic Situation Display



ATM Tactical Information Architecture



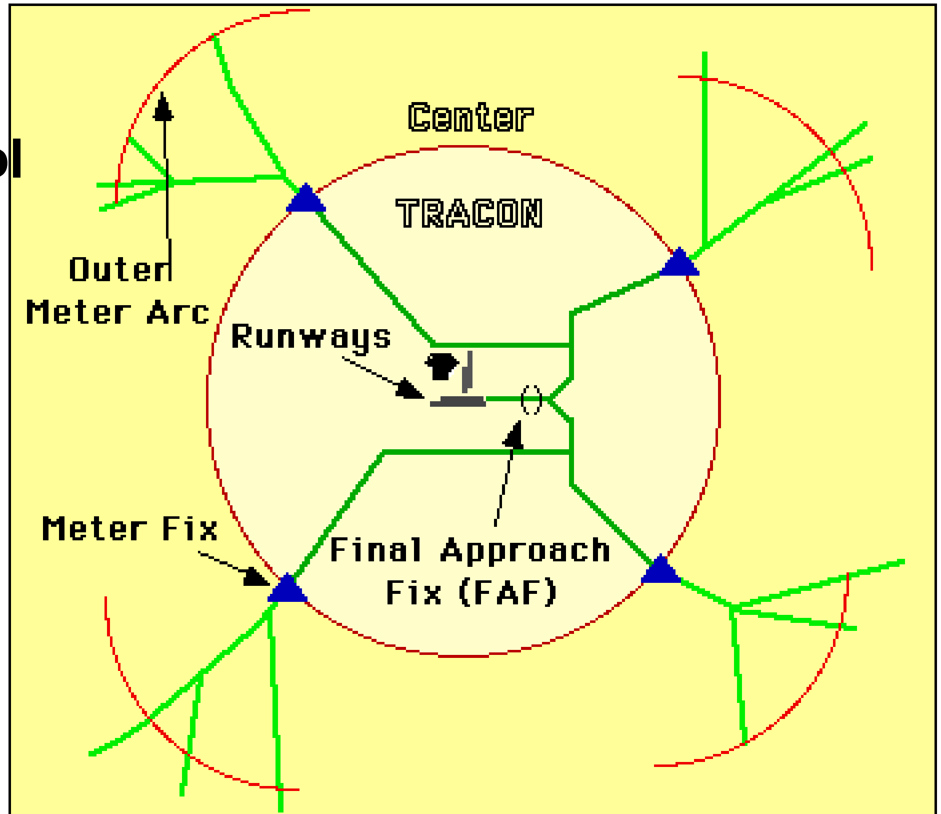
Information Sharing and Decision Support Tools

CTAS
Decision Aid/Information Sharing Example

TMA Traffic Management Advisor
DA Descent Advisor
FAST Final Approach Spacing Tool
- **p FAST**
- **a FAST**

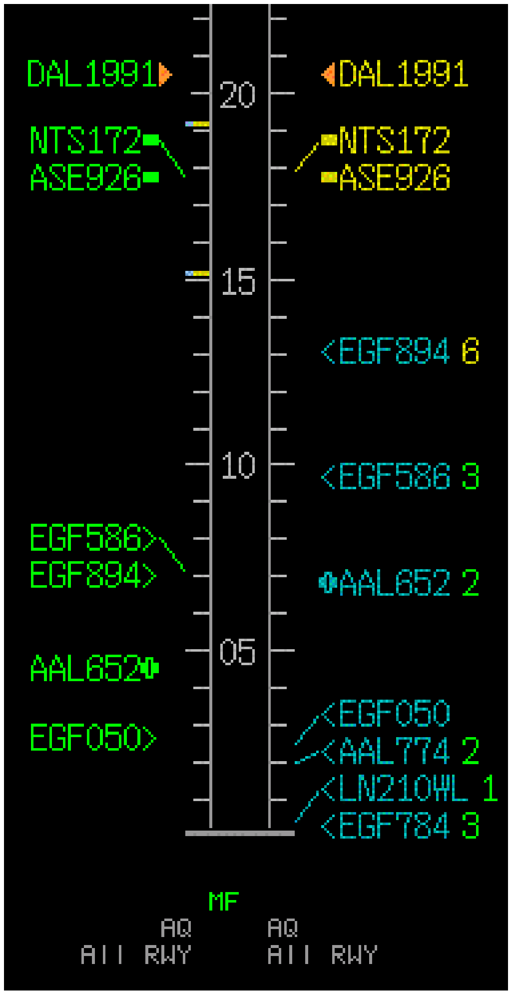
UPR User Preferred Routing
D2 Direct-To Tool
EDP Expedite Departure Path
CAP Collaborative Arrival

Future (?)
SMS Surface Movement System
DP Departure Planner
DAG Distributed Air Ground



TMA Scheduling Reference Points
(diagram is not to scale)

ATC Coordination Example CTAS Traffic Management Advisor (TMA)

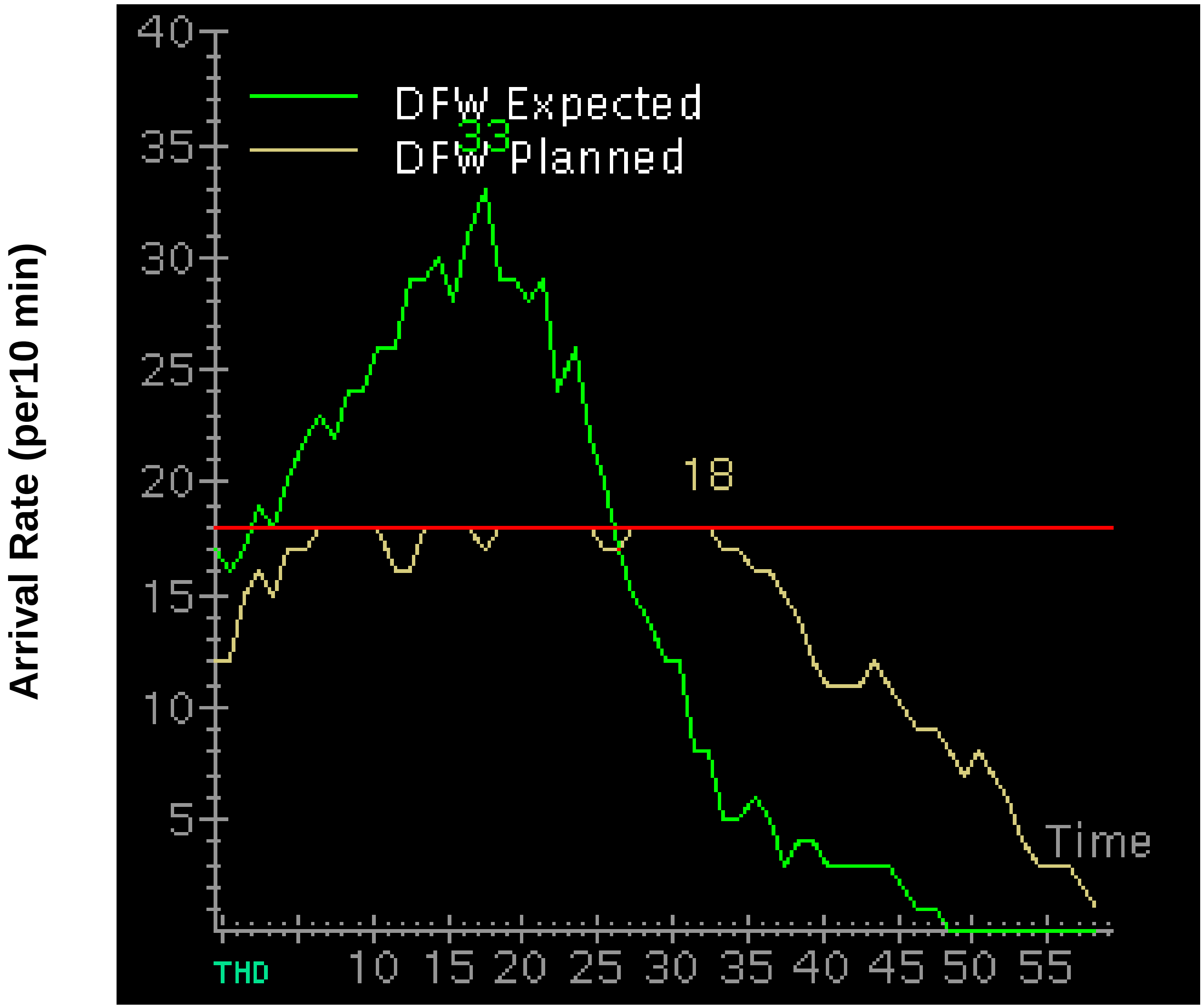


ETA STA

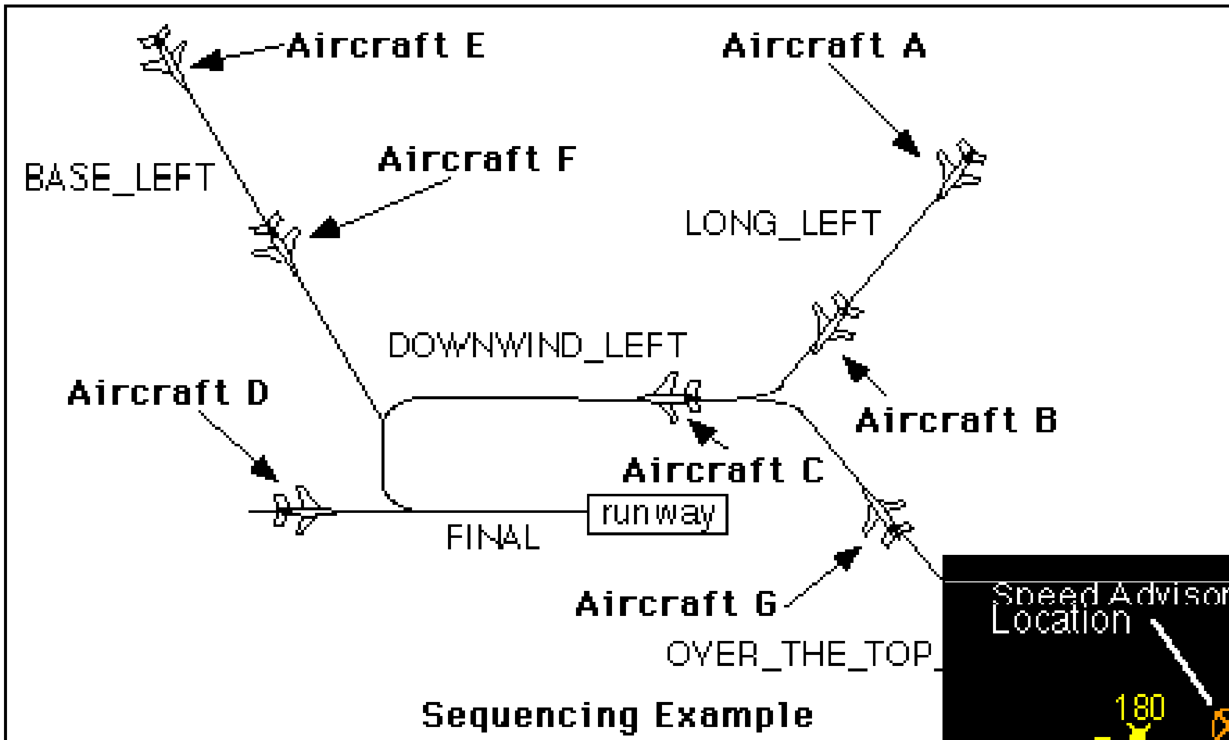
TMA Provides

- Decision Support
  - Scheduling
  - Resource Allocation (Runways)
- Information Sharing
  - TRACON
  - Center (ARTCC)
  - TMU/TMC

CTAS Load Graph



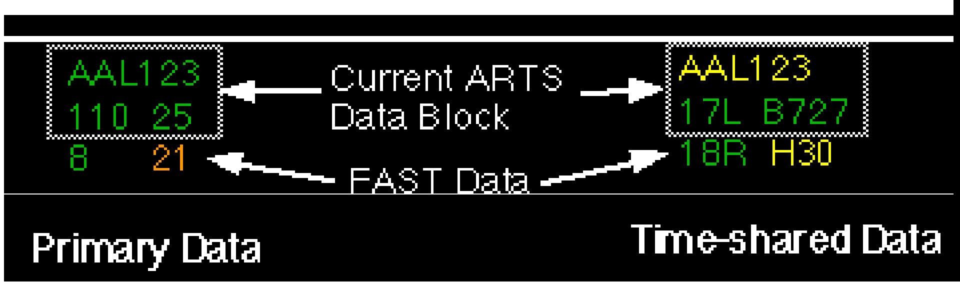
FAST



p FAST
Sequencing
Runway Advisory

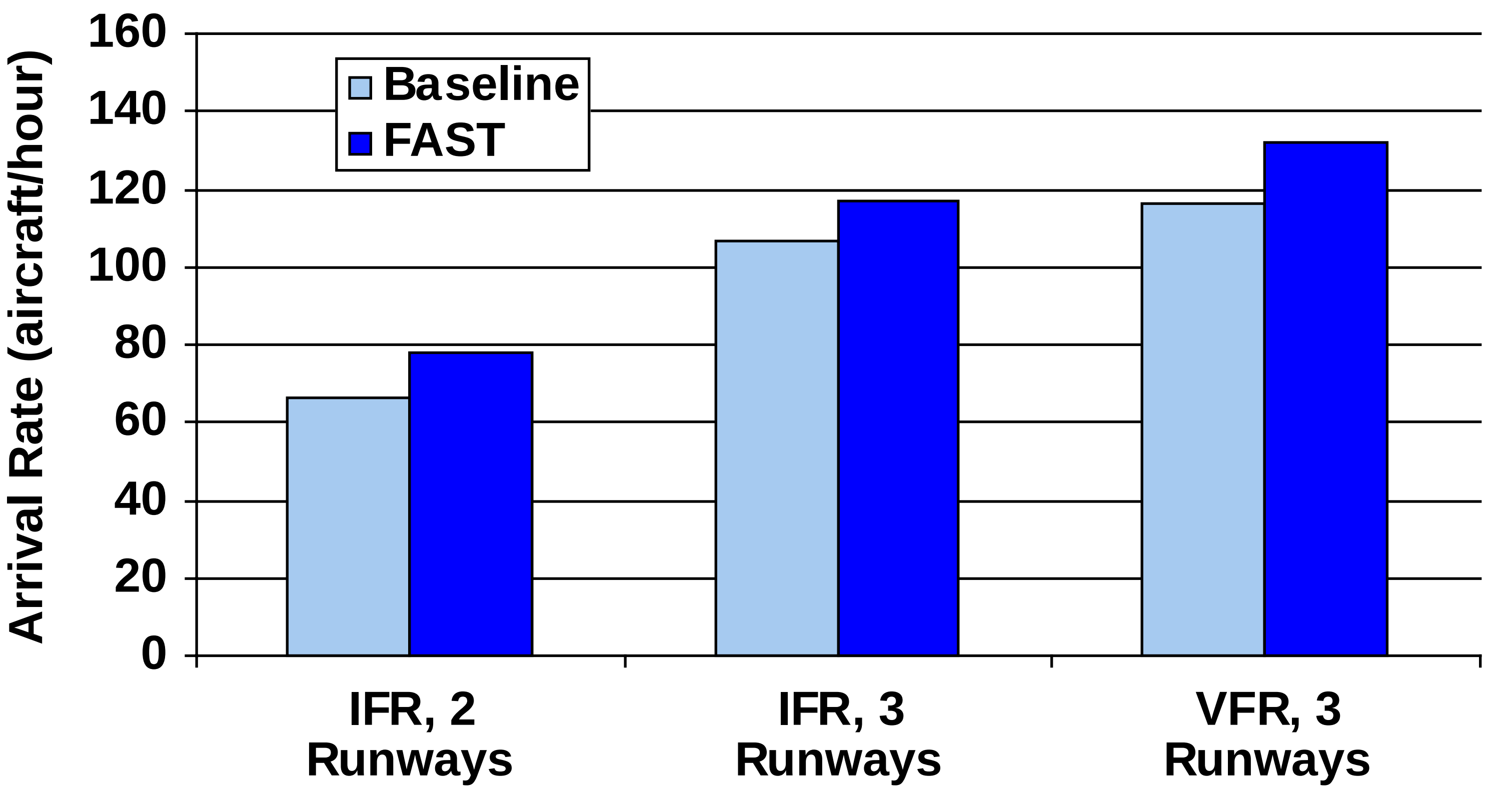
a FAST
Speed Advisory
Turn Advisory

FAST Speed and Turn Advisory Graphics



ARTS Flight Data Block with FAST Enhancements

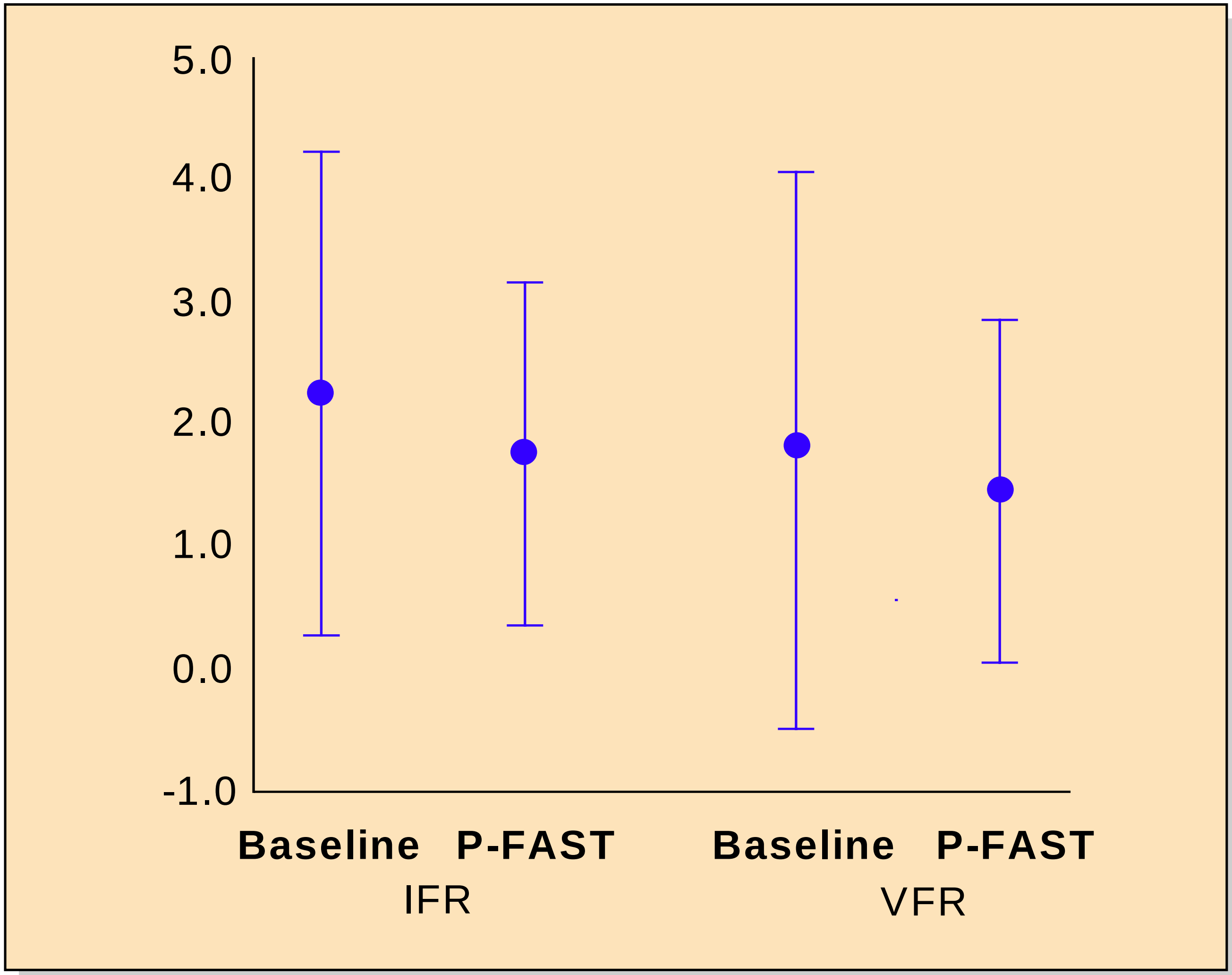
Passive FAST vs. Current (DFW Trials)



11:30 am rush,
VFR corrected for inboard landings

From Tom Davis (NASA Ames)

Passive FAST vs. Current (Excess in-trail Separations)



DFW
11:30 am rush,
measured at
Outer Marker

From Tom Davis (NASA Ames)

Departure Planning Tools

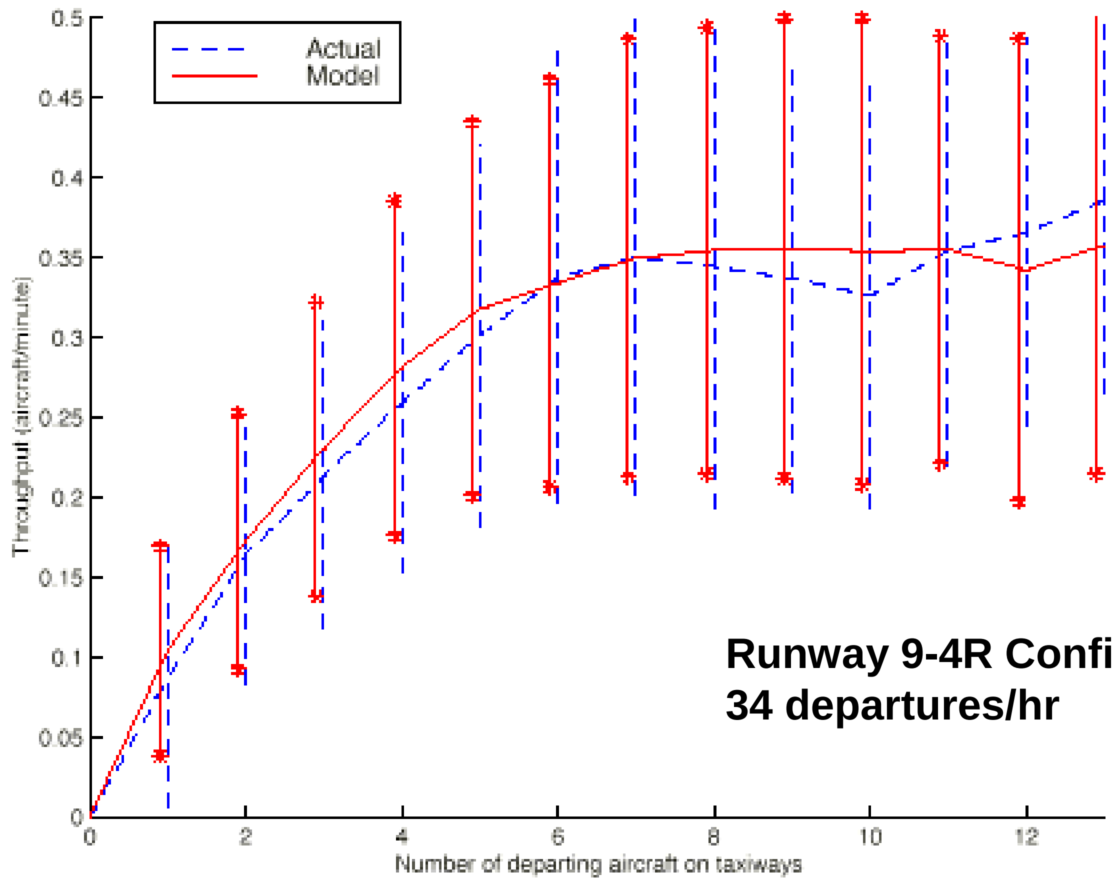
- **Decision Aiding Tools to Improve the Efficiency of the Departure Process**

- **Meter and Sequence Departure Queues to:**
  - ☐ Utilize system resources efficiently (primarily at peak traffic)
    - ◆ **Maximize runway throughput**
    - ◆ **Minimize taxi time delays (pushback and other clearances)**
    - ◆ **Balance runway loads**
  - ☐ Minimize environmental impact
    - ◆ **Engine emissions during taxiing**
    - ◆ **Noise regulations**
  - ☐ Reduce economic inefficiencies
    - ◆ M**inimize "engine-run" (taxi) times**
  - ☐ **Guarantee fair treatment among all airport users**

- **"Virtual Queue"**

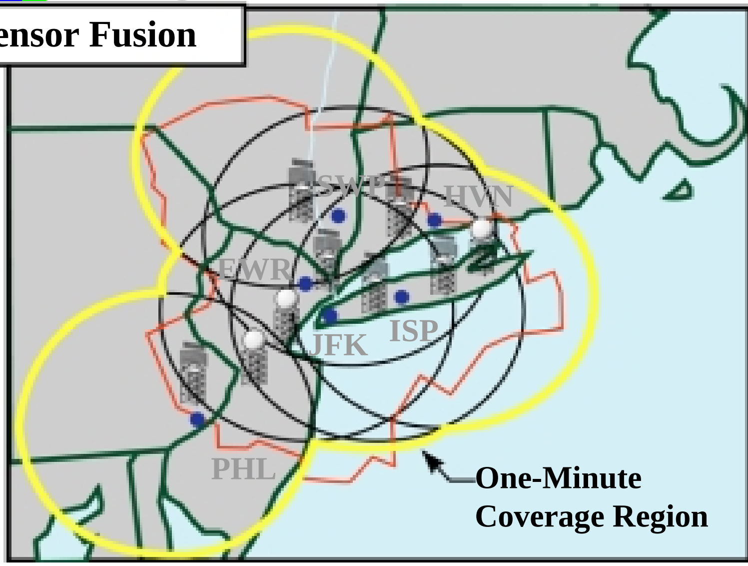
Departure Planning Tool 1 (N Control)

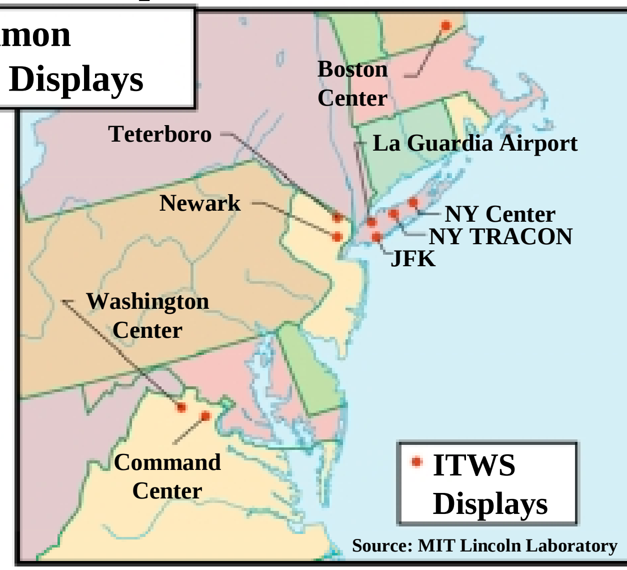
$\overline{T_5}$(t+6 min.) as a function of N_{dep}(t) in configuration 9 (ASQP data, Boston Logan, 1996)

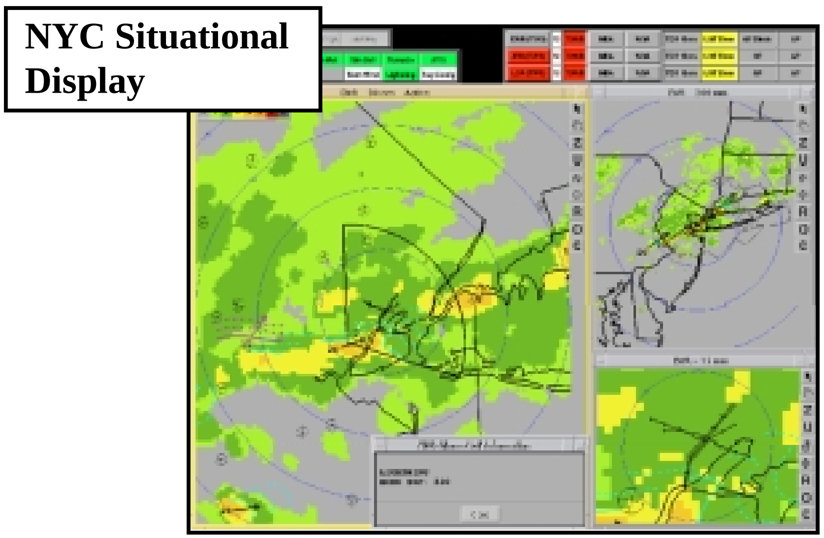


Runway 9-4R Configuration
34 departures/hr

Weather Decision Aid Example
New York City ITWS

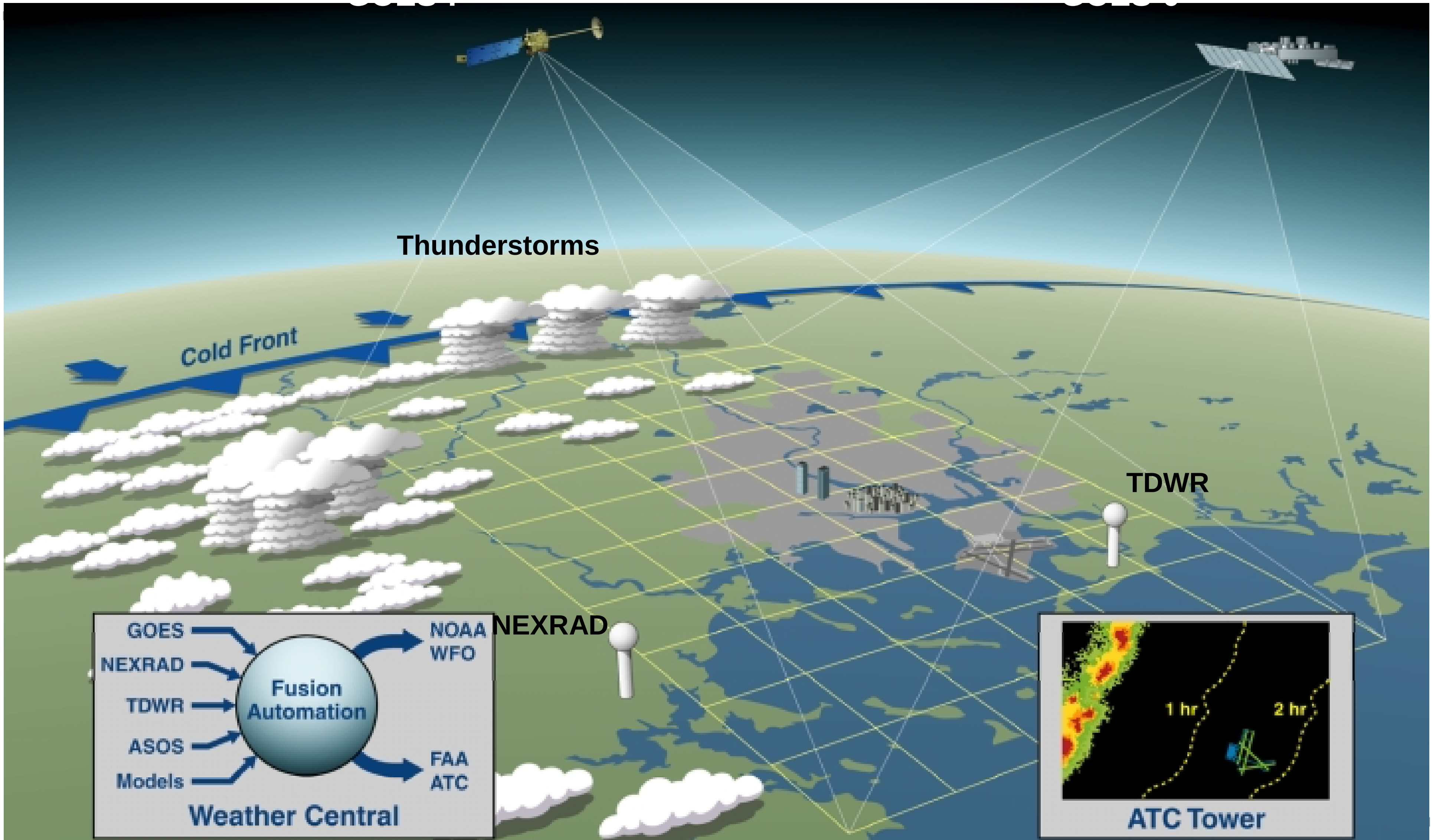






Source: MIT Lincoln Laboratory

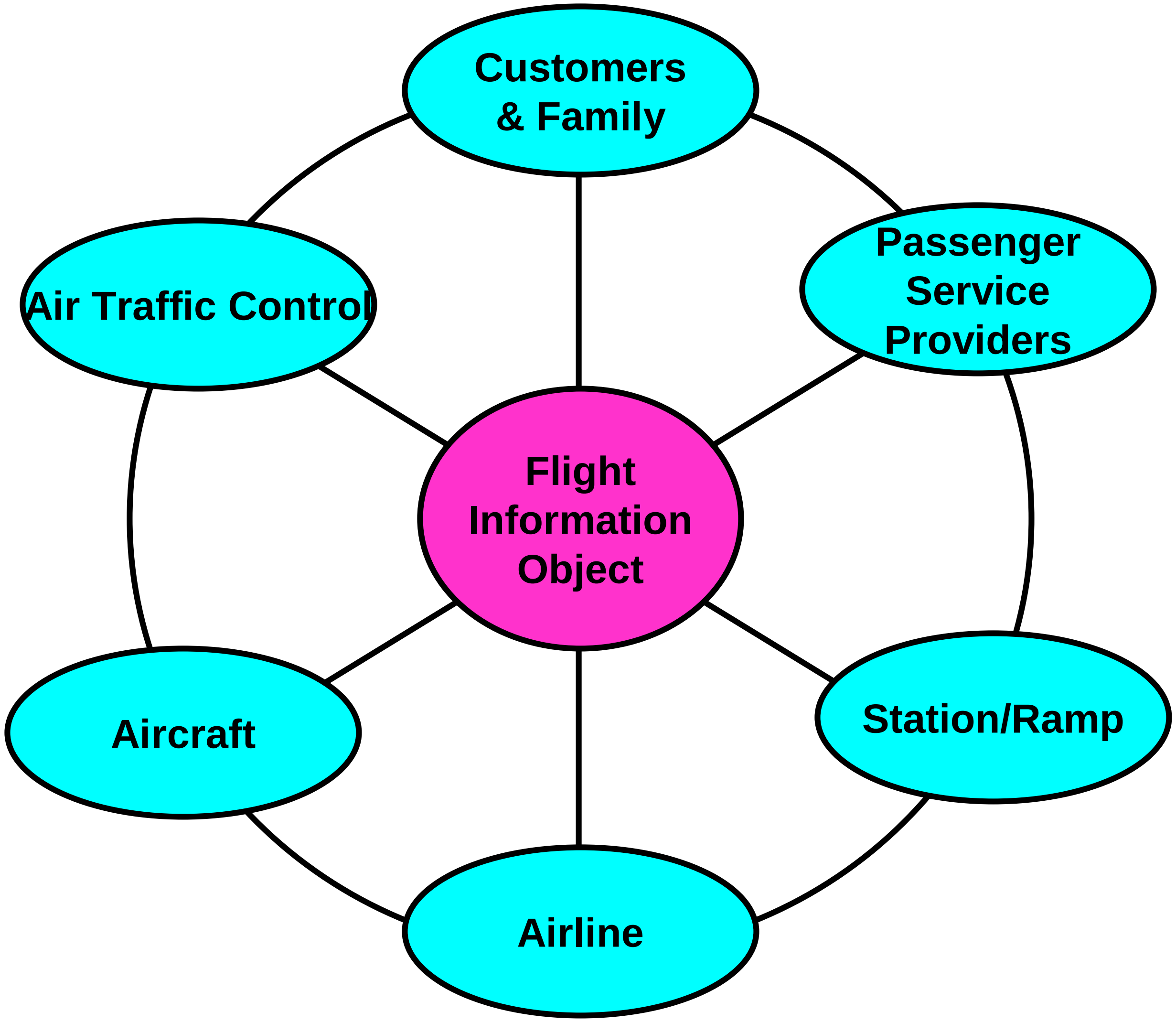
Future Synoptic Civil Weather



340522_1.ppt
CBS 4-7-2000

Source: MIT Lincoln Laboratory

Database *Example*
Flight Information Object (FIO)



Capacity Increase Potential
Free Flight Phase 1

- **Collaborative Decision Making**
  - Improved Coordination of Limited Resources
- **URET Conflict Probe**
  - No Direct Impact
- **Traffic Management Advisor**
  - Improved Runway Balancing
  - Flow Coordination
- **p FAST**
  - Runway Load Balancing
  - Runway Schedule Compression (10-15%)
- **Surface Movement Advisor**
  - Limited Gate Coordination
- **Controller Pilot Datalink Communication (CPDLC)**
  - No Direct Impact

Potential Future Improvements to Capacity Management

- **Time Based ATM Operations**
  - Required Time of Arrival (RTA)
- **Formation Approach Procedures**
- **Integrated Terminal Multi-Airport Operations**
- **Airport Capacity Markets**
  - Arrival Departure Balancing
- **Automated Passenger Screening**
- **Integrated Multi-Modal Transportation Systems**

Suggested Political Solutions to Capacity Shortfall

- **Privatization, the silver bullet?**
  - ☐ **May improve modernization,costs and strategic management**
  - ☐ **Limited impact on capacity**
- **Re-regulation**
  - ☐ **Increased Costs**
- **Peak Demand Pricing**
  - ☐ **Reduced service to weak markets**
- **Run System Tighter**
  - ☐ **Requires improved CNS**
  - ☐ **Safety vs Capacity Trade**
- **Build more capacity**
  - ☐ **Local community resistance**
- **Multi-modal transportation networks**

Conclusion

- **Technology in Pipeline will have limited impact on peak Capacity at Currently Stressed Airports**
  - 20% to 40%
- **System will become (is) Capacity Restricted**
- **Airlines will Schedule in Response to Market Demand**
  - Delay Homeostasis
  - Increased Traffic at Secondary Airports
  - High Frequency Service
- **Technology will not be a panacea**
- **Overall system response is not clear**
- **Need for leadership**

Capacity Limit Factors

- **Airport Capacity**
  - ☐ Runways
  - ☐ Gates
  - ☐ Landside Limits
  - ☐ Weather
- **Airspace Capacity**
  - ☐ Airspace Design
  - ☐ Controller Workload
- **Demand**
  - ☐ Peak Demand
  - ☐ Hub & Spoke Networks
- **Environmental Limits**
  - ☐ Noise (relates to Airport)
  - ☐ Emissions (local, Ozone, NOX, CO_2)

Schedule Factors

- **Peak Demand/Capacity issue driven by airline Hub and Spoke scheduling behavior**
  - Peak demand often exceeds airport IFR capacity (VFR/IFR Limits)
  - Depend on bank spreading and lulls to recover
  - Hub and Spoke amplifies delay
- **Hub and spoke is an efficient network**
  - Supports weak demand markets
- **Schedules driven by competitive/market factors**
  - Operations respond to marketing
  - Trend to more frequent services, smaller aircraft
  - Ratchet behavior
  - Impact of regional jets
- **Ultimately, airlines will schedule rationally**
  - To delay tolerance of the market (delay homeostasis)
- **Limited federal or local mechanisms to regulate schedule**

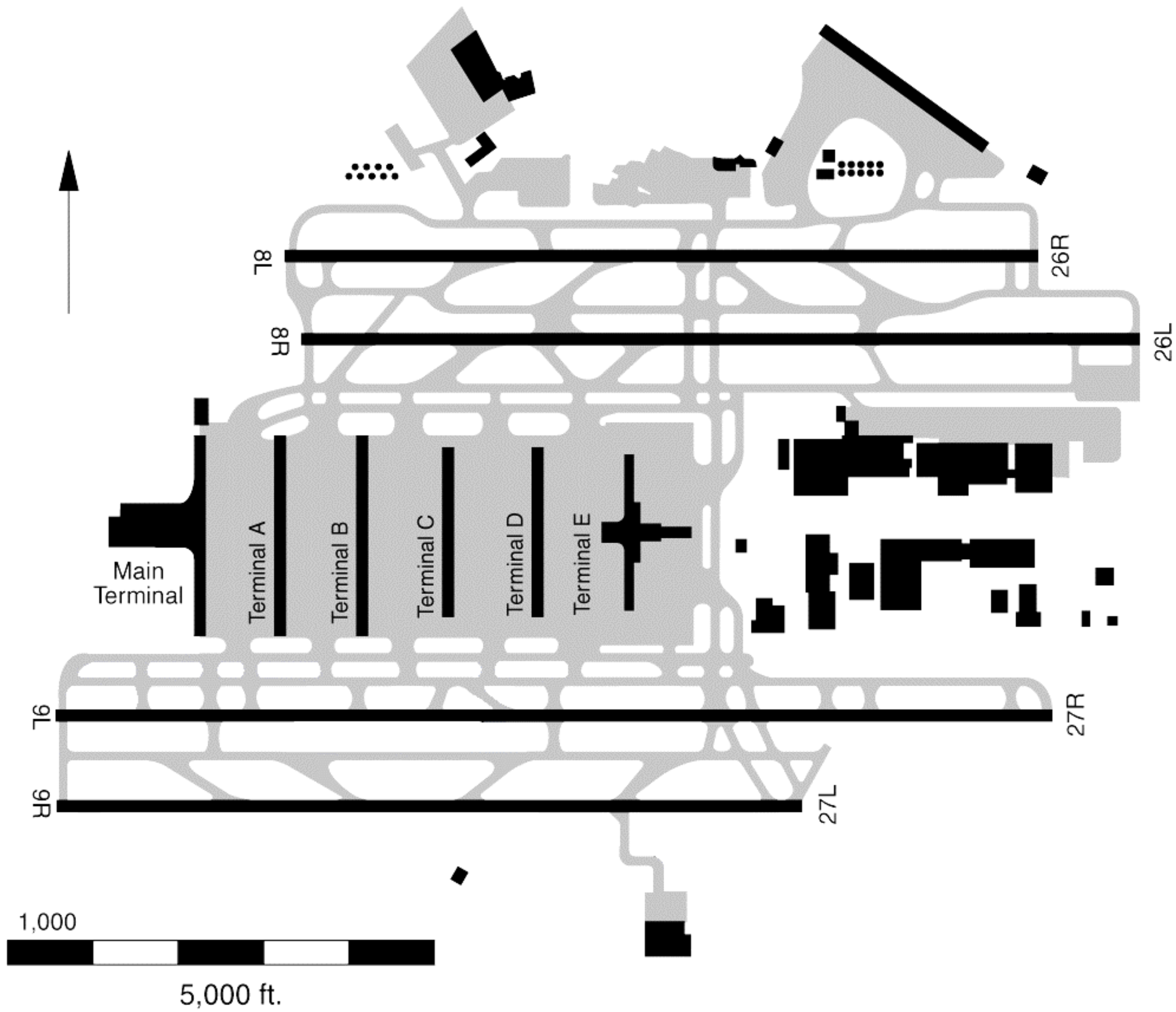
Capacity Limits as Market Drivers for Large Aircraft ?

- **Do large aircraft increase passenger throughput?**
  - ☐ Wake Vortex Separation Requirements
  - ☐ Runway Occupancy Time
  - ☐ Taxi Speeds
  - ☐ Aircraft Turn Time
    - ◆ Southwest (25-30 min)
    - ◆ International (3-5 hours)
- **Can you incentivize/require larger aircraft?**
  - ☐ Landing Fees
    - ◆ Currently charge by weight/size (disincentive)
    - ◆ Peak period pricing
      - Impact on secondary markets (cost, schedule)
      - Political Issues
  - ☐ Slots
    - ◆ Used in Europe (still have large delays)
    - ◆ Not used in US except (LGA,DCA,ORD,JFK)

Airport Issues

- **Gate Design**
  - 80m box, jetways,
- **Taxiway Design (80m box)**
- **Runway Loading/Wear**
- **Taxiway Loading**
  - Tenerife
- **Emergency Response Capacity**
- **Community Noise**
- **Landside limits**
- **Maintenance Facilities**

Atlanta Hartsfield (ATL)



CAPACITY ENHANCEMENT

SINGLE STREAM COMPRESSION

ARRIVAL COMPRESSION

- FINAL SPACING DST
- LANDING SEQUENCE OPTIMIZATION
- FMS/ATM INTEGRATION
- REVISED IN-TRAIL SEP STANDARDS
- DYNAMIC WAKE SPACING - ARRIVALS
- CDTI/ELECTRONIC VFR
- HIGH SPEED EXITS
- DECELERATION OPTIMIZATION
- RWY EXIT GUIDANCE

DEPARTURE COMPRESSION

- WAKE VORTEX DEPARTURE AID
- DEPARTURE SEQUENCE OPTIMIZATION
- REVISED DEPARTURE STANDARDS

TERMINAL AREA

MULTI-RUNWAY INTERACTIONS

- RWY ASSIGNMENT DST
- CONVERGING RWY SPACING AID
- PARALLEL RWY MONITORING
- RWY CONFIGURATION DST
- ARRIVAL/DEPARTURE PLANNING
- PAIRED PARALLEL APPROACHES
- REVISED MULTI-RWY STANDARDS

FLOW TO FINAL

- HOLDING STACK MANAGEMENT DST
- ARRIVAL FLOW MANAGEMENT
- DYNAMIC RESECTORIZATION
- WX IMPACTED ROUTING DST
- MISSED APPROACH GUIDANCE
- CURVED APPROACHES

SURFACE

- TAXI GUIDANCE
- SURFACE SURVEILLANCE
- SURFACE MOVEMENT DSTs
- LOW/ZERO VISIBILITY TOWER

SYSTEM LEVEL

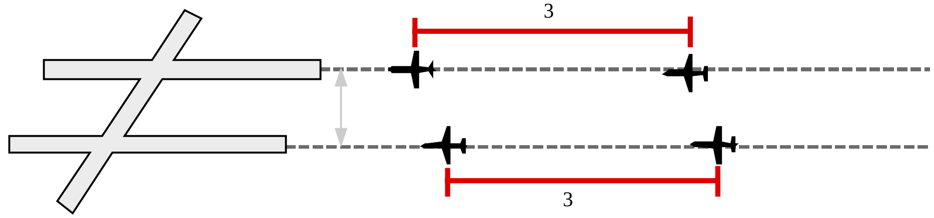
GENERAL

- NEW TFM PROCEDURES
- ADVANCED TFM DSTs
- WORKLOAD REDUCTION
  - improved CHI
  - datalink
- NOISE REDUCTION
- AIRSPACE REDESIGN
- SYNTHETIC VISION (LANDING)

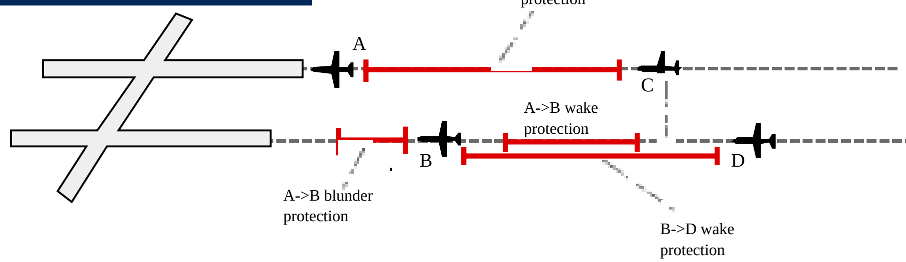
WEATHER

- WINDS ALOFT
- CONVECTIVE WEATHER PREDICITON
- CEILING/VISIBILITY PREDICTION
- WX FORECAST PRODUCTS
- WEATHER PENETRATION

INDEPENDENT PARALLEL APPROACHES



PAIRED PARALLEL APPROACHES



DEPENDENT PARALLEL APPROACHES